Bessemer Steel

Ores and Methods

Fitch

BESSEMER STEEL.

ORES AND METHODS.

NEW FACTS AND STATISTICS RELATING TO THE TYPES OF MACHINERY IN USE, THE METHODS IN VOGUE, COST AND CLASS OF LABOR EMPLOYED, AND THE CHARACTER AND AVAILABILITY OF THE ORES UTILIZED IN THE MANUFACTURE OF BESSEMER STEEL IN EUROPE AND THE UNITED STATES; TOGETHER WITH OPINIONS AND EXCERPTS FROM VARIOUS ACCEPTED AUTHORITIES.

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CONTENTS.

CHAPTER I.

ORES.

CHAPTER II.

METHODS.

CHAPTER III.

METHODS.

CHAPTER IV.

METHODS.

CHAPTER V.

THE BASIC-BESSEMER PROCESS.

CHAPTER VI.

THE HARRISON STEEL COMPANY.

CONCLUSION.

PREFACE.

The papers presented to the public in this volume were prepared at the request of the Miners' and Manufacturers' Association of St. Louis, during the past summer, and it was not supposed by me that anything further than the usual newspaper publication would ensue; many members of the Association, however, having expressed the opinion that the matter herein presented might prove of practical value to those engaged in this great industry; and although it is not improbable that in the haste with which the labor was done, some errors may have found place, in the main, I believe, the statements to be correct and reliable, and have consented to the issue of this book.

Hoping that the work may be of benefit to its readers,

I am, truly yours,

Th. W. Fitch

St. Louis, Mo., September 2[illegible], 1882.

CHAPTER I.

ORES.

THE QUANTITY, QUALITY AND COST OF THE IRON ORES OF THE UNITED STATES, GREAT BRITAIN, GERMANY, FRANCE, BELGIUM, SWEDEN, SPAIN AND ITALY, AND MANUFACTURE OF SPIEGELEISEN.

In the following paper will be found a brief review of the iron ore resources of the United States, Great Britain, Germany, France, Belgium, Sweden, Spain and Italy, as obtained from reliable sources of information.

The Iron Ores of the United States.

Of the 8,000,000 tons of ore now annually raised in the United States, a portion belongs to the clay or carboniferous measures, while the remainder takes the form of either hematities or oxides. The richest ores are those of the Lake Superior and Lake Champlain districts. In Pennsylvania, Missouri, New Jersey, Alabama and Tennessee there are likewise large and valuable deposits of ore. For the purposes of the steel manufacturer the ores mostly in request up to this time have been those of Lake Superior. The openings from which the ore is obtained in this region are from 200 to 300 feet long, from 100 to 200 feet wide and about

600 feet in working depth. The ore formerly cost from \$2.50 to \$4 per ton at the mines, and contains from 60 to 66 per cent of metal; it now costs from \$3 to \$5 at the mines for hematite and \$6 for best specular. Some of the mines in the Lake Superior region have already been exhausted, but new mines have been discovered.

Considerable deposits of a similar character exist at Menominee, lying to the south of the mines just referred to, and are now being worked extensively. In the Lake Champlain district the ore is found in pockets, much in the same manner as in the region of Lake Superior. At Port Henry the ore is obtained partly by open and partly by close mining, the former about 250 feet square by 250 in depth, and the latter a continuation of the mineral deposit to the dip. From the present floor of the quarry or open portion a bore hole of 140 feet passed through pure ore without reaching the rock. The roof of the mined portion of the excavation is supported by five colossal pillars of pure ores estimated to weigh 70,000 to 80,000 tons. The selling price varies from \$5 to \$7; the yield is from 60 to 62 per cent, but it contains too much phosphorus to be useful for Bessemer steel by acid process.

About eighty-five miles in a westerly direction from Philadelphia is the deposit of ore known as the Cornwall banks. Its percentage of metal is much below that of the two districts already referred to, being only 50 to 55 per cent. It is perhaps the most cheaply worked mass of ore in the world. It lies in the form of a ridge nearly three-quarters of a mile long, having a width of 500 feet, and a height in some places of 350 feet above the surrounding plain, and a depth below it of 50 to 180 feet.

The ore is so soft in texture that a man for a day's work can blast and load 10 tons into the wagons, which ascend the hill by a spiral locomotive railway cut in the ore all the way.

The produce of Cornwall banks is contaminated with sulphur—possibly the most sulphureous ore of its kind in the world. This deleterious ingredient is in a great measure removed in the blast furnaces by the copious use of lime, and the ore being free from phosphorus, the resulting pig iron is in favor at the Bessemer steel works. The producing powers of this remarkable accumulation of ore are very large, probably—if fully exercised—amounting to some thousands of tons per day.

At a distance of about eighty miles in a south by west direction from the city of St. Louis lies the Iron Mountain, and in its vicinity are the deposits of Pilot Knob and Shepherd Mountain. The mineral of the specular variety is very hard and dense. The first mentioned, and by far the most important of the three deposits, is an irregularly-shaped deposit in many places of clean solid ore of various thicknesses up to seventy or eighty feet. The ore sells at St. Louis at about $8 per ton, and it yields about 67 per cent of iron. In former times it was delivered at $6 per ton. The second quality of ore, containing from 50 to 60 per cent of iron, and which is too high in phosphorus for the acid process is sold for about one-half the price asked for the first quality ore.

The mineral at Pilot Knob occurs as a bed or seam about thirty feet in thickness. It is very hard, and in consequence more expensive to work than that obtained at the Iron Mountain. It is also less rich in metal, being only 56 or 57 per cent, and sells at St. Louis at about $7 per ton. The second quality of this ore brings only about one-half the price of the first, and these second ores are suitable for the Basic process, although unfit for the acid process.

About 100 miles in a south-westerly direction from the City of St. Louis in the Counties of Dent, Crawford, and Phelps, which section is known as the "Southwest Ore Dis-

trict," there has been developed a large number of ore banks extending over a considerable area. The Simmons Mountain and the Cherry Valley bank have yielded nearly 350,000 tons of ore, and large amounts are still in sight yet undeveloped. In Iron County there is evidence of large deposits of ore which have been verified by shaft prospecting. The character of the ore in these counties is blue, specular, and red hematite, usually found mixed in the same mine, the specular appearing in large boulders. The average of numerous analyses, made by Prof. Wuth of Pittsburg, demonstrates these ores to be low in silicious matter, and varying as to phosphorus from 0.04 to 0.12, and that they are almost absolutely free from sulphur. The specular contains about 66 per cent of metallic iron and the red hematite about 55 per cent of metallic iron.

The ores of New Jersey belong chiefly to that class known as magnetite, but the deposits are thinner than those of Michigan, Pennsylvania and Missouri, and are more costly to get.

The ore lies in veins varying in width from a foot or two to forty feet, but in the larger masses foreign matters are interspersed. The cost, under circumstances differing so widely varies much. From $3.75 to $4.75, including 5 per cent for rent, is said to represent the cost price of the ore at the pit's mouth. The percentage of iron is about 55, but the content of phosphorus unfits the New Jersey ore generally for the Bessemer acid process.

In various localities among the elevated regions of the Apalachian chain, and in the adjacent low lands, as well as elsewhere, are found deposits of the hydrated oxide of iron or brown iron ore. This ore contains so much foreign matter that it requires washing. Delivered at the blast furnaces its cost is about $3 per ton. It contains more phosphorus than the magnetic ores of New Jersey.

In Virginia brown ore, yielding 50 per cent of iron, is mined for 50 cents per ton, and delivered at the blast furnaces for about $1.50 per ton. Large deposits of this kind of ore are also found in the States of Alabama and Georgia, yielding from 45 to 50 per cent of iron, and costing about $1.25 per ton delivered at the iron works, which, of course, are near to the mines. Hitherto the presence of phosphorus has prevented this ore from being employed for Bessemer steel making; but the complete elimination of phosphorus being now an accomplished fact, this stone can be adopted for such a purpose.

The Red Mountain, of Alabama, is a fossil ore deposit, extending over seventy miles. The vein has a working width of about ten feet, and the ore is of good quality to probably 100 or 150 feet, when it becomes too calcareous as a rule. Many millions of tons are already proved in this ridge, which is in the midst of coal fields, and being rapidly developed by the furnaces at Birmingham. Its average richness in iron is about 52 per cent. Its cost at mines is about $1.25 : cost to furnaces owning mines (i. e., mining expenses), 85 cents.

Large deposits of red fossiliferous ore are found in the Apalachian chain, sometimes exceeding thirty feet in thickness. This ore yields in the furnace about 40 per cent of iron, and it is extracted for about 50 cents per ton. In the north of Tennessee the same description of ore is found in considerable quantities, but the cost of working it is so much greater that it costs about $2.50 per ton at the works. Northwards this bed of fossiliferous ore gradually diminishes in thickness. The iron obtained from the fossiliferous bed is of fair quality.

Among other deposits of ore in the United States remarkable both for quantity and quality may be classed that in the Cranberry vein in North Carolina. It has been worked at its eastern extremity on a small scale for some years, and

has recently been traced for miles in a westerly direction through the Smoky Mountains.

Taking all the iron ore raised in Great Britain, Mr. I. L. Bell has estimated its average per centage of iron to be a trifle under 35 per cent; whereas the produce of the mines of the United States, similarly considered, will be about 56 per cent, which means that for each ton of iron made there is 20 cwt. less ore to be dealt with by the American ironmaster.

Less than 12 1-2 per cent of the total quantity raised in Great Britain is fit for the Bessemer acid process; whereas in the United States almost one third of the produce of its mines is sufficiently free from phosphorus to furnish iron fit for Bessemer purposes by the acid process.

There is quite a large amount of iron ore at Iron Ridge, Wis., distant about 160 miles by rail from Chicago, owned by the North Chicago Rolling Mill Company, and will be used by them for making basic pig metal in their blast furnaces at South Chicago. It is a cheap ore, easily mined, and by analysis contains—iron, 51 per cent; phosphorus, 1.34 per cent; silicon, 5 per cent.

The production of iron ore in the Lake Superior district in 1881 in gross tons was 2,336,335; in State of New Jersey in 1881, 737,052; in Lake Champlain district, New York, 1881, 637,000; in Cornwall ore bank, Pennsylvania, 1881, 249,050; total production of iron ore in census year 1880, net tons, 7,974,705; imports of iron ore in 1881, 782,887.

In view of the large amount of iron ore contained in the United States, it appears surprising that we should have imported nearly 800,000 tons last year, but that was caused by the scarcity of ores mined, suitable for the manufacture of Bessemer pig for the acid process, for which there was a large demand, and consequently high prices were charged for the domestic ores.

It would seem, however, by the following figures, that the foreign ores cost nearly as much at the furnace as the high priced ores of the Northern States, and that the real remedy lies in a more extensive use of the cheap ores of the Southern States for the production of steel at less cost.

The minimum prices free on board ship are about: commom ore, 48 and 51 per cwt., at Parman, say $1.50; common ore, 48 and 51 per cwt., at Carthagena, say $1.75: rich pure ore, 55 and 58 per cwt., at Bilboa, say $2.00; rich pure ore, 65 per cwt., at Marbella, say $3.00; rich pure ore, 65 per cwt., at Elba, say $3.00; rich pure ore, 52 per cwt., at Oran, say $2.20. To these prices must be added freight, insurance, and landing charges. Steamer freights for the year 1881, on ore per ton, averaged about $3.00; the duty is 20 per cent *ad valorum*, so that Bilboa ore would cost on dock in this country about $5.40; and the Marbella and Elban ore, which is quite as good as Lake Superior ore, would cost $6.60 at dock. Adding the landing charges and inland freight would make the cost of these imported ores about $8.40 at Pittsburg for Bilboa, and $9.60 for Marbella.

The Manufacture of Spiegeleisen in America.

Up to the present time the greater part of the spiegeleisen used in the Bessemer Steel Works of America has been imported from Europe.

In 1870, the manufacture of spiegeleisen was undertaken by the New Jersey Zinc Company, at Newark, N. J., which has three furnaces, each 20 x 7 feet, with a combined annual capacity of 5,000 gross tons. In 1872, they produced 4,072 tons; in 1873, 3,930 tons: in 1874, 4,070 tons. The spiegeleisen made by this company is said to be equal to the best that is imported, and is, therefore, readily sold.

The following are two analyses of it :

Iron	83.250	83.23
Manganese	11.596	11.67
Phosphorus	.196	.19
Silicon	.367	.99
Carbon	4.632	4.02
Total	100.031	100.10

Pig iron that is rich in manganese, and almost free from phosphorus, silicon, and sulphur, is required for use as spiegeleisen.

In 1875, the Bethlehem Iron Company and the Cambria Iron Company commenced to make spiegeleisen from Spanish ores.

In the same year the Woodstock Iron Company undertook the manufacture of spiegeleisen from the rich ores of Alabama. It is expected that before long America will be quite independent of European supplies of this material. Three States made spiegeleisen in 1881—New Jersey, Pennsylvania, and Ohio; the total production for the year was 21,086 net tons, of which 16,276 net tons were made in Pennsylvania by Carnegie Bros. & Co., Limited, and by the Cambria Iron Company.

The manganese of Arkansas is mainly developed in Independence County. It is here not in veins but in mass deposits, much like limonite in occurrence, but more solid and regular. These ores will yield about 40 to 50 per cent manganese, and are in large quantities, and new discoveries are being made monthly. It is probable that no deposits as large as these have yet been discovered in America of this class of ore. Much of it is low in phosphorus and suitable for spiegel, but being low in iron would require admixture of iron ore in the furnace.

The Iron Ores of Great Britain.

The Bessemer process heretofore has been dependent on ores of exceptional purity, and since steel has so largely taken the place of iron, the supply of such ores had become a question of paramount importance in relation to the future of this industry.

In the manufacture of steel by the Bessemer system acid process much above one-tenth of a unit per cent of phosphorus renders pig iron unfit for use. Ores, therefore, that contain, as the great bulk of English ores do, a much larger percentage of phosphorus have not hitherto been utilized, because practically all this deleterious matter finds its way into the ore.

Of the total quantity of iron ore raised in Great Britain, I. L. Bell has calculated that less than 12 1-2 per cent is fit for the Bessemer steel manufacture by the acid process, but by the basic process the clay and calcareous ores of the United Kingdom are now used in the manufacture of Bessemer steel.

About 18,500,000 tons of iron ore of all kinds are now annually used in the United Kingdom.

Hematites, which are the ores hitherto almost exclusively used in the Bessemer process, are contributed mainly by Lancashire and Cumberland, these counties furnishing indeed about 90 per cent of the total production of this kind of ore in the United Kingdom.

The richest deposits of English hematite ores are found in the Furness and Whitehaven districts.

The somewhat uncertain conditions under which much of the hematite ores of the northwest coast are found cause them to be more expensive than the ordinary clay or calcareous ironstones. I. L. Bell puts the cost of Cumberland ore at $2.50 at the mine, and states also that the payment of

royalty amounts to 75 cents per ton. To the same authority we are indebted for the information that the approximate cost of conveying the minerals required for the manufacture of a ton of hematite iron in this district is greater than that of any other district in the United Kingdom, except South Wales, as the following tabulated statement of the approximate cost of conveying the minerals required for making one ton of pig iron in Great Britain shows:

	CARRIAGE OF FUEL.		CARRIAGE OF ORE.	
West of Scotland	cwts. 44	$ .44	cwts. 43	$ .94
West of Scotland	" 65	.47	" 38	1.03
South Staffordshire	" 40	.37	" 55	.69
Cumberland	" 24	2.39	" 36	1.13
Lancashire	" 24	2.45	" 36	1.13
Lincolnshire	" 25	2.44	" 70	.69
South Wales	" 40	.44	" 45	3.38
Middlesborough	" 26	.75	" 65	1.00

	CARRIAGE OF LIME STONE.		TOTAL.
West of Scotland	cwts. 14	$ .29	$1.67
West of Scotland	" 14	.42	1.92
South Staffordshire	" 10	.12	1.18
Cumberland	" 8	.14	3.66
Lancashire	" 8	.14	3.72
Lincolnshire	" 0	.00	3.13
South Wales	" 15	.18	4.00
Middlesborough	" 12	.37	2.12

The united make of the above is equal to five-sixths of the entire kingdom.

The amount of iron ore (including chrome) imported into the United Kingdom during the year 1881 was as follows:

	Tons.	Value.
Newport	532,226	£458,538
Cardiff	447,449	376,084
Middlesborough	389,093	382,087
Newcastle	252,817	237,900
Glasgow	197,804	241,441
Swansea	94.194	88.201
Stockton	85,179	76,821

Sunderland	75.309	75,309
Workington	51,678	54,519
Chester	43.738	48,689
Ardrosan	42.209	44,680
Hull	38.482	48,221
Fleetwood	31.045	30,240
Liverpool	30.225	39,119
South Shields	29.203	27,378
Hartlepool	20.656	21,550
	2,361,407	£2.250.846
Other ports under 20,000 tons each	89,291	98,565
	2,450,698	£2,349,411

A calculation of these totals shows the value per ton of ore to be about $4.70 in our money.

The manufacture of spiegeleisen in Great Britain is largely increasing, and now amounts to nearly 100,000 tons annually, of which the largest quantity is produced in South Wales.

The Iron Ores of Germany.

The iron ore resources of Germany embrace nearly all principal varieties of the mineral, including bog ore, brown hematite, spathic carbonate, blackband, clay ironstone, hematite, limonite, and magnetic ore. The chief mining district is that of Bonn, which embraces Westphalia, the Rhine, Hesse-Nassau, and Waldeck. In this district there are about 950 separate mines, producing 1,500,000 tons of ore per annum. The next most productive district is that of Silesia, where there are about 100 mines, yielding about 500,000 tons yearly. The largest yield is obtained from the magnetic deposits, whence 1,250,000 tons are annually extracted. The spathic deposits are next in importance, yielding from 600,000 to 700,000 tons per annum, and following these come the hematites, of which about 500,000 tons are annually raised.

All the indigenous ores of Germany are expensive when compared with those native to England and America, if the deposits of Alsace-Lorraine are excepted. In Rhenish Prussia specular iron ore costs about $5.00 per ton ; red hematite, with 45 per cent iron, $2.75 per ton ; brown hematite, $3.50 per ton ; and spathic carbonates, $4.50 per ton, delivered at works.

At the Kœnigin-Marien-Huette Works, which are said to be the largest of their kind in Saxony, mild Bessemer steel is made, containing a considerable percentage of manganese and without spiegeleisen. The ores are obtained from 80 different mines belonging to the owners of the works, and are situated in various parts of Saxony, Bavaria, and Thuringen. The average percentage of iron is as follows: Red hematites, from lodes in granite, in the Saxon Eizgeberge, contain manganese, but free from phosphorus, up to 55 per cent of iron. More silicious varieties from Bavaria contain 45 per cent. Magnetic ores, Saxon, up to 60 per cent ; Bavarian, up to 40 per cent, the latter being somewhat pyritic. Brown iron ores and altered spathic ores, up to 35 per cent ; liassic ore from Upper Franconia, somewhat sandy, up to 40 per cent ; spathic ores from Thuringen and Ruess, up to 35 per cent ; nodular clay iron ore from the coal measures of Zwickau, up to 40 per cent.

The brown ores and coal measure carbonates are roasted in heaps ; the other kinds are charged in the furnace without roasting. The charges for Bessemer iron consist of mixtures of red hematite and spathic ores, the other varieties being used in the furnaces producing foundry and forge pig iron. The average composition of the Bessemer pig is shown by the following analysis :

Carbon, combined	1.095
Carbon, graphitic	2.936
Silicon	2.200
Manganese	3.450
Phosphorus	0.070 to 0.120
Sulphur	trace.

In Germany, spiegeleisen was formerly produced by charcoal out of manganiferous iron ores, its singular peculiarity being due to the presence of 10 to 12 per cent of manganese, on which the Bessemer process depends for its success.

The average consumption of charcoal per 100 pounds pig metal was about 120 pounds ; the average daily production during the year about 4 1-2 tons.

In the practical working of the furnace the spathic ores yielded about 38 per cent of iron. But on account of the devastation of the forests, and of the scarcity of hard wood suitable for conversion into good charcoal, this fuel soon after 1859 proved insufficient to produce the spiegeleisen wanted, and it became necessary to replace the charcoal by coke.

German Spiegeleisen and Ferro Manganese.

The first development of manufacturing spiegeleisen by means of coke was attended by many difficulties which at times seemed insurmountable, but they were finally overcome and quantities of the new iron was soon introduced into the rolling mills and other works and found preferable to the best iron previously known, and the only kind that would enable Bessemer steel manufacturers successfully to carry out the process. Ever since that time the demand has exceeded the supply

Two specialties in which the German ironmasters have had more experience than those of other countries are the manufacture of spiegeleisen and ferro manganese, and to the production of Basic pig. In the Rhenish Provinces and in Westphalia, spathic ores from the Siegen District are smelted with a slight addition of highly manganiferous limonites. The calcined spathic ores average 48 per cent of iron and 9.5 per cent of manganese, while a specimen of the limonites, moist, ran 18 per cent of iron, 14 per cent of manganese, 0.2 per

cent of phosphoric acid, and 25 per cent of moisture. Selected spathic ores alone would do for making ordinary spiegel running 10 to 12 per cent; but as they are scarce, an addition of ores richer in manganese is generally made. Manganese has a strong tendency to enter into the cinder, so that, with good working of the furnace, from 40 to 50 per cent of the entire quantity in the ore is found in it; the percentage of manganese in the cinder ranging from 6 to 9 per cent. It does not pay to attempt to put more than 60 per cent of the manganese contents of the ore into the spiegel, because the consumption of coke runs up too high, the production declines, and the spiegel shows gray spots, due to the presence of silicon, which makes it unsalable. A trial at Oberhausen with the ordinary charge yielded mottled metal holding 14.5 per cent of manganese and whitish-gray cinder containing only 3 per cent of manganese. Hot blast is beneficial in the manufacture of spiegel, but it is possible to supplant any lack of heat in the blast by an increase in the charge of coke. The method of charging appears to have very little effect upon the manufacture of spiegel—a fact which Herr Schilling attributes to the fusibility of ores and cinder. The hearth must be carefully investigated, because the spiegel corrodes the brick work rapidly, and escapes through the smallest cracks. It seems that the 10 to 12 per cent of manganese is alloyed perfectly with the iron, because many analyses made of the first and last portions of a cast show no difference in the percentage of manganese. The Geisweid and Wissen furnaces have the largest production, yielding 80 tons of spiegel per day, the consumption of coke is about 2,400 lbs. per ton, with a temperature of blast of 1,000 degrees Fahrenheit.

In running on higher grades of spiegel, 19 to 21 per cent, the limonites are used in greater quantity, and as they are high in gangue, the yield of the charges declines to 38 per

cent, and the proportion of cinder to metal becomes more unfavorable. On an average, only 60 per cent of the manganese in the ore goes into the metal. The proportion between high grade and ordinary spiegel in reference to ore in charge is 28 to 33 respectively; as to the production, it is 7 to 10: and as to consumption of coke, it is 14 to 10. This grade of spiegel does not cut the furnace much, nor does it form accretions, so that the furnace can be run for months uninterruptedly. In changing the furnace from low to high-grade spiegel, it is advisable to make the first charges particularly rich in manganese, so that there is no inconvenience through the casting of a series of intermediate grades. Of late the German works have been forced to import high-grade ores from Cartagena, Spain, because their own run too high in phosphorus. The cinder made in casting high-grade spiegel is more basic, and does not contain quite as much manganese as that resulting from the smelting of ordinary spiegel. The brown smoke issuing from the stack, however, proves, that in making 20 per cent spiegel, the loss through volatilization of manganese begins to tell.

The great difficulty first experienced in making ferro manganese was the formation of accretions, especially with furnaces provided with a cinder-notch. The furnaces made only runs averaging from one month to ten weeks. This has now been overcome, and they are made to produce regularly for ten months. In making ferro manganese, the losses of manganese are not confined to its being carried off in the cinder. In running on 60 to 70 per cent metal, as much as 17 per cent of the manganese in the ore is volatilized, the loss being much greater even on 80 per cent ferro manganese. The cinder obtained in producing 40 per cent metal holds about 7 per cent of manganese, which runs up to 10 per cent as the grade approaches 75 per cent. From 18 to 20 per cent of manganese enters into the cinder when the

ores are too easily fusible. On an average, the yield of manganese is 66 per cent of the quantity contained in the ore. In Oberhausen, the production of 60 per cent ferro manganese is 700 tons per month, the grade being very uniformly maintained. The German founders of spiegeleisen have, therefore, succeeded, during the last ten years, in overcoming many of the vexatious inequalities of working and of product attending the smelting of highly manganiferous ores.

The Iron Ores of France.

The future of the steel trade of France must, of course, be largely determined by the extent and duration of its supplies of iron ore suitable for the manufacture of that metal. The total production of native ore has been returned by Prof. Jordan at 3,000,000 tons. Of this quantity 150,000 tons are magnetic ore, brown hematites and spathose ore, 300,000 tons are red hematite, 1,000,000 tons are oolitic ore, and 1,550,000 tons are hydrated ores of various kinds.

About one-half of the ore used is imported from Belgium, Germany, Spain, Italy, Algiers and other countries, principally from Spain and Algiers.

The deposits of iron ore in France, although numerous enough, are either so limited in importance or so coarse in quality that they are incapable of feeding any considerable number of blast furnaces, with the single exception of the great oolitic formation in the east of the country.

The largest field of red hematite is in the department of the Ard'eche, near the towns of Privas and La Voulte, and it is worked for the supply of the blast furnaces of the Horme, Terre Noire, La Voulte Besseges companies. The production varies from 250,000 to 300,000 tons a year.

The most extensive iron ore field of France is the great oolitic deposit which originates in the Belgian portion of

Luxembourg, and extends through Lorraine up to and beyond Nancy, in the Upper Moselle valley. The yield of iron contained in the ores varies from 20 to 35 per cent ; the proportion of phosphoric acid, feeble enough at times, not unfrequently goes up to 1 per cent, and this is especially the case in the calcareous ores, and in some parts even as much as 1.75 per cent has been found. With regard to sulphur traceable to the existence of some pyrites, it is only feebly, but still sensibly manifested in the ores of the Lower Moselle, but it disappears altogether from those of the Upper Moselle. By making a careful classification and selection of the productions of the various layers, skillful ironmasters succeed in manufacturing iron of very good commercial quality out of the ores in question.

France lost a considerable portion of these ore deposits by the war of 1870-71 ; amongst others those of Hayange and Mayeuvre (now belonging to Alsace-Lorraine), which supply the blast furnaces of Messrs. de Wendel with ores yielding as much as 35 per cent iron. Prior to the full settlement of the dephosphorization problem these ores have been unsuited to the manufacture of steel, but the phosphoric ores of the Moselle are now adapted for steel making purposes, and the prospects of France in reference to this industry assume a much more favorable complexion.

France has imported deposits of spathose iron ore in the Alps and Pyrenees. The sparry or spathose iron worked in the department of the Ise're has for many years past been supplied to the few and unimportant works scattered up and down that slope of the Dauphiny Alps, but it is only recently that patiently conducted researches, over a period of several years, have demonstrated the importance of the great deposit at Allevard, of which Schneider & Co. are now the proprietors.

The Allevard ore is a quadri-carbonate of iron, manganese, lime and magnesia, wherein the iron greatly predominates,

accompanied by a silicious gangue. It is almost entirely exempt from phosphorus. According to Messrs. Schneider, the ores contain in their raw state 32 per cent iron and 2 to 6 per cent manganese, with only .02 per cent of phosphoric acid.

In the Franche-Compte and Berry districts there are deposits of granular hydrated iron ores, containing scarcely a trace of phosphorus and from 34 to 70 per cent of iron. About 350,000 tons are annually raised from these deposits, but the cost of working is too heavy to adapt the ores for other purposes of the highest class.

The average yield of all the French ores has been estimated by Jordan to be about 38 per cent. Alike in quality, therefore, and in quantity, the indigenous iron ore supplies of France are yet inferior to those of either Great Britain or America.

The Iron Ores of Belgium.

As the native ores of Belgium are neither sufficient in quantity nor equal in quality to the supply of the steel works, the great bulk of the ores in this manufacture are imported. Among the ores indigenous to Belgium are the oligist (specular ore) and carbonated iron, found in the primary soil in layers underlying the schistose beds. Generally the limonites form pockets, sometimes connected with carbonated iron. The iron veins are entirely limonitous. The most important deposit in the shape of layers is that of oligist (specular ore), which, in the environs of Vedrin, is remarkable for its unbrokenness and extent. It is composed of several layers more or less near each other in stratification, corresponding with the quartz schistose-condrusian stage. Its northern flat joins nearly vertically the bed of the southern border of the carboniferous basin, to which it serves as a cover. The use of the oligist is becoming very

extensive, and it is exported into France and Germany. The limonite is found especially in pockets, sometimes in a state of real veins, and formed by the decomposition of the pyrites. It produces strong iron of excellent quality. Its output is nearly altogether used by the Belgium iron workers. Its principal beds may be grouped as follows: (A), ores of Entre-Sambre et Meuse; (B), ores of the Scheld; (C), ores of the Meuse; (D), ores of the Ourthe; (E), ores of the Vesdre; (F), ores of the Luxembourg; (G), ores of the Campine; (H), ores of the Brabant.

The carbonated iron is only met with in partial beds. The sparry iron ore of the coal mines accompanies some beds, of which it pervades the roof and the wall.

Little more, however, than 1,000,000 tons of ore are annually raised in Belgium itself, and about an equal quantity is imported; but notwithstanding these drawbacks, the Seraing works compete favorably for Bessemer rail orders with the most advantageously situated works in the United Kingdom. Of coal and coke the Belgium steel works have an unlimited supply close at hand.

The iron industry of Belgium was saved from complete ruin from want of ores or fuel at three distinct periods of its history. When charcoal became scarce and the use of coke stepped in to replace it, Huart-Chapelle, at Marcinelle, in 1854; Lejeune, at Hourpessur Samble; Hansnet, at Cauvin, and John Cockerill, at Seraing, were the leaders of the coke movement. Then, again, when the ironstone of the country had in a great measure been worked out, the owners of the blast furnaces of Ougree in 1853 discovered how to utilize the vast beds of hematite scattered over the country, which had not been used since 1790, because they produced coal short iron. The process adopted consisted in mixing a certain proportion of the shales of the neighboring coal measures along with the ore in the furnace. And,

lastly, when these hematite ores became quite insufficient for Belgium consumption, the ninettes of the Grand Duchy of Luxembourg came into notice, and have continued to this day a chief resource. With collieries, most of which are worked under very great difficulties, with ores which have to be carried a hundred miles or more, with laborers who are physically incapable of doing anything like the work of an English workman, the Belgians have by dint of care, order, and especially economy in minor details, been enabled to hold their own as iron makers among the nations of the earth, and to compete in distant markets with Great Britain.

The Iron Ores of Sweden.

Sweden contains a variety of iron ores, some of them of remarkable purity. The mountain ores, or magnetites and specular ores of Sweden, belong, geologically, with but few exceptions, to the primitive formations, the beds being in general much raised and folded, so that the dip is often more nearly vertical than horizontal. The beds are frequently abruptly cut off by dykes and cross courses of various eruptive rocks. The thickness of the ore beds varies from nearly nothing to 100 to 150 feet. The Swedish ores, according to Prof. Akerman, may be classed in three groups—the first occurring in euritic gneiss, and which are remarkable for their richness in quartz; the second, lying in the gneiss rocks proper, and notable for their contents in magnesia, and which, although often smelted with but a minute quantity of lime, at other times can not be worked with the addition of both lime and quartz; the third class of iron ores are principally distinguished by the proportion of maganese, and often occur in the limestone; they are either magnetites or peroxide ores. The large bulk of Swedish ores need fluxing with lime in order to yield a glassy slag, 30 per cent and

upwards of limestone being often requisite for that purpose. As typical "mixing stone" for the Bessemer manufacture, the ores of Gronrot and Norberg, which contain from 6 to 10 per cent of protoxide of manganese, may be mentioned, as also those from Penning, containing 12 to 14 per cent. The still richer ores of Swatburg, Schissyttan, which hold as much as 13 to 20 per cent of the latter valuable substance, are unfortunately accompanied by so much sulphur that they are better suited for making spiegel iron than Bessemer pig. The contents of the iron of the Swedish ores varies between 30 and 70 per cent, but it most frequently lies between 45 and 50. The best Swedish ores are well known to contain very little phosphorus; those of Dannemora, about .003 per cent; those of Persburg, .005 per cent. It is, however, generally found in practice to vary between .005 and .05 per cent. The greater number of silicious specular ores are very free from phosphorus, and some of the magnetic ores have also an exceedingly small proportion of sulphur, although most of the magnetic ores are so interspersed with metallic sulphides (pyrites) that they must be subjected to a very careful calcining before going to the furnace. The temperature of the kilns may be kept so high that the most refractory ores come to sintering, and many ores previously rejected on account of their high contents of sulphur have thus been made serviceable. Some exceptional Swedish ores are not infrequently mixed with bitumen, some with graphite, but oftener with titanium, which, when abundant, increases, as is well known, the consumption of charcoal necessary for their reduction to a very costly extent.

The greatest drawback to the development of the metallurgical industry of Sweden is the scarcity and poor quality of its fossil fuel. Coal is found only in the most southern part of the country—in Skane and in Southern Holland—and as it is not only a long distance from the principal deposits

of iron ore, but contains much ash, and is unsuitable for coking, it is of very little use for metallurgical purposes. In no other part of Sweden is there any likelihood of finding coal, for the rocks which form the mass of the country belong to the Laurentian or primitive formation and to the Silurian period, while the more recent deposits have been formed during the latest geological period. Although in Skane or Scania there are none of the magnetite and specular ores on which the iron industry of Sweden is based, it is considered not impossible that the argillaceous ores may be found, and in this case a trade may spring up in the manufacture of the commoner kinds of iron ; but for the purpose of steel manufacture, Sweden practically occupies the position of a country destitute of fossil fuel ; and hence, excepting in so far as native charcoal is employed, it depends for its supplies of fuel on England. This dependence is likely to become greater from year to year, for the forests of Sweden will not support any great addition to the demands now made upon them. Already in the neighborhood of the iron mines the supply of charcoal is beginning to fail, causing iron and steel makers to go further afield, and thus enhancing the cost of the fuel and augmenting the cost of production. With all these drawbacks, it is scarcely probable that the steel manufacture of Sweden will reach a much greater development than it has already attained, while both in steel and in iron the metallurgy of Sweden must in the future even more than in the past be distinguished for relative superiority in the markets of the world.

Spain.

Spain contributes very materially to the manufacture of steel in other countries. England, France, Germany, and Belgium depend more upon Spain than upon any other country for their supplies of iron ore suitable for the Bessemer

acid process. These ores are chiefly hydrous red, brown, and yellow hematites and spathic carbonates, occurring in the cretaceous formation, and traversing it in the form of great lodes or veins, from 100 to 300 feet wide, which, although frequently more or less coincident with the strike of the stratification of the beds of limestone, shales or sandstones which form the "country," do not always follow the dip or underlay of the beds in depth, and, at places, they diverge and break through the sedimentary strata. The upper portion of these deposits, for a few feet, to even a hundred or more feet downwards from the surface, consists of hydrated oxide of iron, of a red, brown, or yellow color, free, or very nearly free, from sulphur or phosphorus. At greater depths, however, they invariably change into white or grey spathic carbonate of iron (sometimes containing specks of pyrites), which is the original mineral from which, by atmospheric agencies, the oxidized iron, which forms the more superficial portion of the deposits, has been formed. Since the spathic iron ore is infinitely harder and more expensive to work, besides not containing more than from 40 to 45 per cent of metallic iron, the workings hitherto have, in all the mines, been confined to the extraction of the richer oxidized surface ores, which contain from 50 to 60 per cent iron, and require little or no blasting. Eventually, however, as the mines get deeper, the spathose ore must become the staple of exportation, but they must undergo calcination to reach 60 per cent of metallic iron. Attention has also been directed to working the rich magnetic iron ores which are found abundantly in the south of Spain; amongst others, the extensive outcrop of iron ore at Marbella, about midway between Gibraltar and Malaga. This is a compact magnetic oxide of iron, containing an average of about 60 per cent of metallic iron.

It was not until 1870 that the mines of Bilboa and Mar-

bella began to be worked to any extent ; and yet the output of iron ores from these two districts has now reached many millions of tons.

In 1881, 3,239 vessels laden with 2,500,532 tons of ore sailed from the river of Bilboa for foreign ports, and the largest single cargo was 1,690 tons. The export for the first quarter of 1882, exceeded that of the corresponding period in the previous year by 53,000 tons. The quantity of red ore exported exceeds that of other kinds, and unless other deposits are discovered, the present rate of output will cause an exhaustion in about ten years. The brown ore which is in sufficient quantity to last for a long time to come, must, therefore, be considered as the main source of future supply.

Italy.

The most important of the iron districts of Italy is Tuscany, which comprises also the Island of Elba, from which large shipments of ore are made to other countries engaged in the manufacture of steel by the Bessemer acid process.

The analyses of these ores show :

	Calamita.	Terranera.	Rio.
Sesquioxide of iron	94.67	93.36	87 84
Oxide of manganese	0.33	trace	0.07
Alumina	.....	0.58	3.47
Lime	.....	0.16	0.22
Magnesia	.....	0.17	0.34
Silica	3.28	.....	5.97
Copper	0.04	.....	.....
Sulphur	0.03	0.11	0.17
Phosphorus	trace	none	0.01
Insoluble rock	.....	3.64	.....
Water and loss	1.65	1 98	1.91
	100.00	100.00	100.00
Percentage of metallic iron	66.27	65.35	61.81

CHAPTER II.

METHODS.

AMERICAN STEEL WORKS—CARNEGIE BROS. & CO., LIMITED, PITTSBURG—NORTH CHICAGO ROLLING MILL CO., CHICAGO—COST OF LABOR IN THE UNITED STATES AND ENGLAND.

In this paper will be described a few selected steel works of the world, and special attention will be paid the type of the machinery in use, the methods in vogue, and the class of labor employed by these corporations in the manufacture of Bessemer steel.

There are in this country at present fifteen works operated on the Bessemer system, with thirty-seven converters that are capable of producing in the neighborhood of 2,000,000 tons of Bessemer steel annually, according to the capacity converters are made to produce in the United States.

Carnegie Bros. & Co., Limited.

The steel works of Carnegie Bros. & Co., Limited, will first be placed before you. These works are located on the main branch of the Pennsylvania railroad, eleven miles east of Pittsburg The surface area of the works covers about 106 acres, and they enjoy a river frontage on the Monongahela river of 3,300 feet, in addition to the railroad facilities afforded by the Pennsylvania railroad, which traverses the plant. The water supply, which is abundant, is procured from the river, being carried to a well, at which pumps are

placed; thence discharged into tanks, from which supply pipes lead to the works. The works are surrounded by a complete system of tracks. Within the past two years important improvements in blast furnace practice have been successfully inaugurated here. Their C furnace, blown November 8, 1880, turned out by September 1, 1881, 45,028 tons of Bessemer pig iron, this production being an average of 1,070 tons per week for six consecutive weeks; later the furnace made 1,276 tons per week, and has now reached a weekly product of 1,500 tons. The dimensions of this furnace are: Height, 79 feet; bosh, 20 feet; hearth, 9 feet; and it has eight tuyeres, three pounds pillar of blast, three Cowper stoves, 60 feet high and 20 feet in diameter; temperature of blast, 1,100°.

Furnace C is duplicated in furnace B.

In furnace D—their new furnace—the product runs up to 1,640 tons per week, and about 299 tons of gray metal have been made in a day's time; recently this furnace reached a production of about 1,807 tons per week.

These figures will be all the more interesting when it is remembered that ten years ago 700 tons per week was considered an extraordinary yield of the Lucy furnace; 100 tons per day in a furnace being unheard of. Since then these Pittsburg furnaces have made 900, 1,100, 1,200, 1,400, 1,500, 1,640 and 1,807 tons per week and nearly 300 tons in one day. It is not difficult to define the reasons for this exceedingly large output. It may be reasonably ascribed to large hearths, inserted tuyeres, good fuel, good stoves, high temperature of blast, say 1,300° to 1,500°, and plenty of air.

The dimensions of furnace D are: Height of stack, 79 feet 4 inches; diameter, just under the gas outlet, 17 feet 6 inches; the bosh is 20 feet in diameter, and tapers gradually to 17 feet 6 inches to a point 7 feet 4 inches below the top, from which it tapers to a diameter of 14 feet at the

outlet. There is a gradual incline from the bosh to the top of the crucible of from 20 feet to 11 feet 6 inches; the depth of the crucible is 8 feet 6 inches; center of cinder notch to top of hearth, 3 feet 6 inches. Such are the internal dimensions of the furnace which has run out more metal in twenty-four hours than any other furnace in the world.

Furnace D is duplicated in furnace E.

In the converting department are three vessels, ten tons capacity and made concentric, the nose being central and upright when the vessel is blowing, which permits of the metal being taken in at the rear of the vessel. The employment of three vessels allows of two being always in use and thereby delay at the six cupolas is entirely avoided. The cupolas have 8 feet inside lining, 8 ounces pressure of blast, and each of them has a melting capacity of 300 tons of pig daily. The blast supply is furnished to the converters by the blowing engines at a pressure of 25 pounds to the square inch. All the machinery is manipulated by hydraulic cranes with a pressure of 300 pounds to the square inch.

Much of the capacity of the American works for rapid production is due to their general arrangement. The English vessel centers (excepting only in the latest plant) stand but 3 or 4 feet above the general floor, causing the bottom of the casting pit to fall 8 or 9 feet below it, and in this cramped and unventilated space must be performed the largest and hottest manual labor, for there the steel is poured, and the red hot ingots and moulds handled by the men. The vessel centers, on the contrary, are found 9 feet above the general floor in the American plant, and the pit is only 48 inches in depth—just sufficient in depth for convenience in casting. Therefore all the operations of casting are performed, and all the ingots and moulds handled by workmen on the general floor of the building. The freest

of ventilation, easy access and short lifting of moulds are thus obtained.

The high vessel, in addition, permits of the removal of the converter bottoms upon the general floor, and by means of the platforms around the vessels at the level of their center a second story of working rooms is provided ; and from this platform the runners are accessible for repairs and the noses for the insertion of scrap.

The rail mills of Carnegie Bros. & Co., Limited, bloom large ingots and roll blooms into single and double length rails, and the same driving and finishing machinery, which is independent, is used. For rails the three sets of rolls next to the engine are utilized, and the other two sets of rolls are employed for rolling billets, etc. While the rail mills are running the rolls may be changed, so that the whole plant can be engaged on an order for merchant sections without delaying the rail plant. That by this method billets and merchant steel are produced with greater cheapness it is not difficult to understand.

Attached to this mill are eleven Siemens heating furnaces and twenty-eight gas producers in five blocks, a sheet iron cooling tube, leading overhead to the brick gas flue, and two chimneys, each having 6 feet clear diameter, and which are 98 feet high. Hydraulic charging and drawing machinery is also connected with the three ingot furnaces. The 14-inch, three or four-rail ingots are placed in the converting works, while hot, in their respective seats, on a car, ready for charging into the furnaces, and the car is drawn by a locomotive to the front of the heating furnace with an entire Bessemer heat of ingots. This car is so constructed that a long peel can be thrust by hand under the ingot, and by passing the chain around the stationary sheave and hooking it upon the end of the peel and then giving water to the hydraulic cylinder, the chain drives the peel and the ingot

upon it into the furnace. The ingot is then tipped off by the workmen with the aid of the handles, the peel is withdrawn and slipped under another ingot, which the car conveys to the front of the door into which it is to be charged. In front of each furnace door is a fixed sheave, and the hydraulic cylinders lie under the frames that hold the sheaves. The ingots are withdrawn upon the bogie which takes them to the blooming train by sliding over them the yoke to which the chain is then attached.

The ingots are bloomed in two 3-high trains—one 32 and the other 36 inches—after heating in one of the furnaces. The trains are driven by non-condensing horizontal engines.

The blooming train has feeding rollers driven by an independent engine, and also hydraulic cylinders for raising the feeding tables, turning the ingots over and moving the middle roll, in order to vary the size of the passes as required. A telegraph leads to a 3-ton hammer, and another to the shears. A hydraulic crane places the blooms in bogies, and they are taken to the reheating furnaces before passing to the rail train. The rail train consists of three stands of 3-high 23-inch rolls, to which are coupled billet and merchant rolls as before explained. It is driven by a 46-inch cylinder by 4 feet stroke engine, with a 50-ton fly wheel. Two sets of carrying rollers, driven by a saw engine (by means of reversing friction clutches), carry the rolled piece from both these sets of rolls to the saw carriage. Either one or both saws may be used, depending upon the kind and length of the product. Carrying rollers, driven by reversing friction clutches from the saw engine, then take the rolled piece to either of the curving machines and hot beds. The place of the usual hot straight engine plate is occupied by long carrying rollers. Lying upon these rollers the rails are pressed by hydraulic fingers against stops, which are so arranged as to give the rail such a curvature that it will be

nearly straight when cold. Then, by fingers on an endless chain, it is moved out upon either of the hot beds. One man and a boy, by means of levers, operate all this moving and curving machinery and also the saws. The rails instead of being twisted and bent into short curves, as they are by hand straightening and curving, are carried by this method without distortion to the hot bed. As a result they cool almost straight, and are not injured by the gags in cold straightening.

The rails are passed from the other ends of the hot bed to the cold straightening presses; thence to the cold beds; thence to the drilling machine, and, if necessary, to the slotting machines; and lastly out of the mill to the rail-yard. The power of these machines is furnished by an 18x24-inch engine. All rails not of exact lengths are made so by cold saws run by 11x20 inch engines. When double length rails are rolled, the piece is divided in the middle by the hot saw only, and the two fag ends are made the exact length by the cold saw.

The present production of these progressive works per week is estimated at—Blast furnaces, 5,000 tons; converting department, 6,000 tons; rail and billet mills, 5,000 tons.

North Chicago Rolling Mill Company.

Another advanced works of this country is the new plant of the North Chicago Rolling Mill Company, located at South Chicago. The works consist of four blast furnaces 75 feet high and 21 feet bosh and 9 feet hearth. Coke from the Connellsville district, near Pittsburg, is the fuel used. The different ores are stocked under the overhead railroad tracks, each having an allotted space and thus facilitating efficient mixing. The limestone is stocked in the yard in a similar manner and the coke supply is housed in a shed 367 feet long and 99 feet wide.

The works are supplied with fire-brick stoves 60 feet high and 21 feet in diameter, vertical condensing blowing engines, 84 inches in diameter air cylinders, 36 inches in diameter steam, 54-inch stroke, thirty to thirty-five strokes per minute, and 72 boilers 36 feet long, 4 feet diameter. The measurements of the building in which the boilers are placed are 248x96 feet. These four blast furnaces have a capacity of no less than 5,000 tons of metal per week. The converting house is some 600 feet from the blast furnaces and consists of three 10-ton converters placed side by side. The blast of twenty-five pounds to the square inch is supplied by two horizontal engines with steam cylinder 42-inch bore and 60-inch stroke; air cylinder, 66-inch bore and 60-inch stroke.

The pressure pumps for handling the cranes in the steel works are situated in the same building as the blowing engines, and are under the control of the same engineer. They supply 350 pounds water pressure to the square inch. The ladle cranes in the steel works have a backward and forward action, with the usual up and down movement. This converting department is capable of producing 7,000 tons of steel per week, and the general arrangements have been made to effect economical output. The main building is 108x113 feet. The spiegel cupola building abuts upon the main converting building, with a passageway in the wall 18 feet by 6 inches, for the convenience of the runners. The house is 66 feet 4 inches by 55 feet 6 inches, and contains four cupolas of the common form for melting spiegeleisen. The molten metal is taken from the blast furnace up an inclined plane on a narrow gauge track three feet above and in line with the vessel in which the metal is to be converted.

The lining department is situated immediately in the rear of the converting house, about fifty feet distant, and is connected by a line of railroad track running from the hoist,

situated under the vessels in the steel works, to a turntable in the center of the lining department. From this turntable a series of short railroad tracks are laid in such form as to accommodate ladles or vessels bottoms, as the case may be. These ladles or bottoms are placed upon a cast iron truck made for this purpose and run exactly under a fire-proof bonnet, which is supplied with gas from six gas producers, placed close by the lining building. The building for the lining department is mainly constructed for the operation of the basic process, but the details for this object are not yet put in, but at the end of the building where the lining and drying for the acid process is done the results are very satisfactory.

Immediately after the ingots are cast they are taken to the rail mill and charged in heating furnaces, where they receive a uniform heat; thence they are taken to a 3-high train of rolls, which constitute at one and the same time a set of blooming and roughing rolls. The ingot is 12 1-2 inches square, and the bloom leaves the rolls formed for a rail or other shape required. The center of the last pass in these rolls is in line with the center of the first pass in the finishing rolls. The 3-high set of rolls is 40 inches in diameter and —— in length, and is driven by a horizontal engine, 42 inches in bore, 48 inches stroke, sixty-five revolutions per minute and a fly wheel of fifty-two tons. The finishing set of rolls are 2-high and reversing. The formed bloom is carried into these rolls by a line of short feed rollers, driven by a line of shaftings underneath, delivering the piece into the first pass of working rolls, and it is then run through each consecutive groove, being guided into them by an automatic pusher, until the finished bar is produced of three or more lengths as required. These rolls are driven by a pair of reversing compound engines with high pressure cylinder 42 inches bore, 42 inches stroke, low pressure cylinder, 72 inches bore, 42 inches

stroke, running 140 revolutions per minute. After the bar is finished it is passed on rollers to a single saw and there cut as desired, being regulated by a revolving stop guided by a workman. The lengths, when cut, are passed upon rollers between two hot beds, where they receive the necessary sweep by a line of fingers, fixed upon a horizontal shaft controlled by a small engine. The rails which are set to sweep are passed by a circular bar operated by an endless wire rope on two or more pulleys, situated at the extreme ends of the hot beds. These beds are located on each side of the sweeping or bending machine exactly opposite each other, and a rail is placed on each alternately, thus giving the rails ample time for cooling before being drilled. The drilling and slotting is effected by the usual methods.

These works were planned and constructed to simplify the productions of steel by a saving of labor, especially skilled labor, and by a saving of fuel. To accomplish this, heavy and the most approved machinery has been specially adopted to insure a more direct and rapid production of Bessemer steel. The economical advantages of the type of machinery and the methods of working possessed by this mill over the other steel works of the United States, in expert estimation, places the North Chicago Steel Company in the front rank of Bessemer steel practice in the United States.

These are two of the most advanced of the steel works of the United States in their respective though different types of machinery and methods of working.

Cost of Labor in the U. S. and England.

The average cost of labor per ton of pig iron in the United States is about $2.00, and in England about $1.00.

According to the present practice of working in the United States, the cost of labor per ton of steel ingots from the pig is about $2.50 ; and for reducing ingots to rail the cost

of labor is about $5.50, a total of $10.00 per ton from the ore for labor, against about $3.50 per ton in England.

The table below shows the cost of pig iron in the Cleveland district, England, for one-half year to March 31, 1879 (all minerals are given at about cost price). The company own and mine their own minerals:

	Quantity used. Tons. Lbs.	Prices at Works.	Cost per Ton of Iron.
Ironstone	3, 565	$0.976	$3.20
Coal (Calcining)	210	....	.11
Coke	1, 203	2.56	2.79
Limestone	1, 51	.89	.45
Wages	....	....	.69
Stoves and Repairs	....	....	.17
Rates and Taxes	....	....	.08
Total	....	....	$7.49

NOTE.—The average cost per ton, however, in England, is about $10.00.

The cost of a ton of pig at the furnaces in the Pittsburg district in the first part of 1879, is stated to be as follows:

	Quantity used.	Prices at Works.	Cost per Ton of Iron.
Ironstone	1.7	$9.00	$15.30
Coal (Calcining)	none.	....	....
Coke	1.25	2.56⅔	3.20
Limestone	.75	1.15	.71⅓
Wages	....	....	1 25
Stoves and Repairs	....	....	.50
Taxes	....	....	.10
Total	....	....	$21.07

The transportation on raw materials is given at $10.27½ in the United States, against $2.00 in England.

The prices in Pittsburg for puddling or boiling iron May 30, 1881, were fixed at a minimum of $5.50 per ton, to be advanced when selling price exceeded 2½ cts. per pound. Of this sum the puddlers' helpers received about one-third. At Philadelphia, July 24, 1880, the minimum price was

fixed at $4.00, and is still at that figure. These represent the wages in the two sections. In England the same class of workmen—August 1, 1881, a period of prosperity and good prices—received, per ton, $1.75.

The following are the approximate rates of wages for men employed in the iron rolling mills in the Western States:

Guide mill roller, per day	$12.50
Guide mill heater, per day	7.10
Roughers	3.55
Heaters' helper	2.10
Bar mill rollers	8.00
Heaters	5.90
Helper	2.00
Straightener	1.75
Plate mill roller	12.50
Heater	7.95
Catcher	3.90
Puddler	4.75
Puddlers' helper	2.40
Shinglers	8.00
Shinglers' assistant	3.75
Muck roller	10.00
Ordinary laborers	1.50
Machinist	$2.50 to 3.00
Blacksmith	2.75 to 3.25

The rates of wages in most of the Sheffield trades have been kept up to the standard of five years ago, and in many cases they have been advanced, notwithstanding the great depression in business. But, although the rates have advanced, the amounts actually earned are much diminished, from the fact that there is so much less work to be done. The fact must be considered, however, that men can now earn larger amounts in a given time than in former years on account of the increased facilities, which enables them to work much more rapidly. For instance, the steel for round, half-round, flat, and three square files was formerly made square, and the file forger was obliged to hammer it into the

required shape. The same was true of steel for cutlery, including razors, edge tools, and many other articles. Now the steel comes to the hand of the forger from the manufacturer already rolled into shapes suited for the various purposes for which it is designed, thus saving much time and trouble to the forger. The use of machinery also in many operations which were formerly done by hand labor, is greatly to the advantage of the workman, since he now receives as much per dozen for the articles he makes as he did formerly, when he could only turn out one-half or two-thirds as many in a day. In such cases machinery has been the friend of the workingman, although he has been in the habit of looking upon it as his enemy.

The following are approximately the rates of wages paid in England:

Puddlers, per day	$1.50
Helpers	.90
Shinglers	2.25
Assistants	1.50
Rollers	2.00
Assistants	1.25
Plate rollers	3.00
Heaters	2.75
Laborers	.90
Machinists	1.25
Blacksmiths	1.50

CHAPTER III.

METHODS.

FOREIGN STEEL WORKS—WILSON, CAMMELL & CO., DRONFIELD, ENGLAND—THE BARROW HEMATITE IRON AND STEEL WORKS, ENGLAND—WEST CUMBERLAND IRON AND STEEL COMPANY, ENGLAND—THE RHYMNEY STEEL WORKS, ENGLAND.

Steel Works of Wilson, Cammell & Co., Dronfield, England.

The steel works of Wilson, Cammell & Co., Dronfield, England, are of the old English type, excepting that the pits are shallow. There are four 8-ton vessels in two pits, and there is a traveler over the vessels for setting bottoms. The vessel bottoms are set in dry and rammed from the nose of the vessel. The tuyeres are 16 in number, with 13 holes of 3-8 of an inch diameter. The ingots are top-cast and sand-covered; they are slowly and carefully poured, but no funnel is used, and they measure 12 1-2 inches at the bottom and 11 inches at the top, and rarely exceed 1,700 pounds in weight.

"Stickers" are punched out of the moulds by means of a hydraulic press. The output for 4 vessels is about 9,000 tons per month, running 10 1-2 tons per week. Statistics of one month shows 46 turns, 195 tons per turn—8,970 tons per month, and this output does not keep the rail mill going to full capacity. The Bessemer plant operates smoothly

and a good mixture of iron is kept on hand. It is stated that 65,000 tons of ingots have been made without a bad heat.

The products follow in one direction from the pig bank to the rail yard, over a space of 600 by 200 feet, and with a minimum of handling and diversion. The first line of heating furnaces stands 60 feet from the line of the Bessemer pits. From the furnaces the ingots pass in a direct line through the blooming, roughing and finishing trains (at the same heat), to a central hot straightening plate. There are hot and cold beds, and finishing tools on either side. Eight small heating furnaces with two doors each are used. The furnaces are all single and coal fired; they are charged from a bogie by hand, and are drawn by means of a hand winch. The ingot is wheeled an average of 80 feet to the train. The bloom runs out of the reversing blooming train upon a car, which carries it by means of a power chain straight ahead 80 feet to the table of the 3-high roughing train (4 fixed power rollers). The reversing finishing train stands in line with the roughing, just like ordinary stands of roughing and finishing rolls, but the two trains are quite independent, and are driven, of course, by independent engines. The bottom finishing roll stands in line with the middle roughing roll. Power carriages are on the front side of these trains, by which the piece is transferred laterally from the last roughing to the first finishing pass.

The blooming train is an old clutch reversing train rebuilt for the purpose. The speed of the rolls is moderate, but this allows the piece to enter without chattering under a large reduction; and as the piece is short, and the feeding is rapid, the seven passes are made in fair time. The carriage, running from the blooming to the roughing tables, is driven on a slightly inclined railway, by an endless chain,

movable by means of a clutch attached to the engine which drives the roughing feed rolls. The boy who runs the feed engine of the blooming train works this clutch to bring the empty carriage back; the roughing feed boy brings the bloom up when he wants it. In normal practice the piece does not stop, and is not touched with bar or tongs from the last pass of the blooming to the back table of the roughing.

The roughing train is driven direct by a horizontal condensing engine making 52 revolutions.

The front fixed table consists of 4 18-inch rollers 3 feet apart, driven exactly like the blooming feed rollers, by a reversing engine. The floor plate around these rollers is a wrought iron armor plate which is nearly on a level with the tops of the rollers. The piece falls out of the upper passes upon this heavy structure instead of being let down by a moving table. The rear table must be a lifting table. It is a flat wrought iron plate 24 feet long by 7 feet 1 inch wide, resting on a frame of 2 2-inch channel bars, and otherwise stiffened. The table is hinged in the rear on a link, so that it can move forward and back; its inner end is raised by a hydraulic piston, acting through an underneath rock-shaft which also carries a counter weight. The inner end of the table is connected to the housings by short links in such a way, that as the table rises it is moved 16 inches towards the rolls with increasing rapidity, thus throwing the piece into the grooves. There are short rollers fixed in and projecting just above the top of the table, and space to suit the increasing length of the piece. The workmen stand on the table and the lifting handle is attached to it. The piece drops out of the last top roughing pass upon the seat, and is pushed back up an incline, off the end of which it falls in front of the first finishing pass. The table is 16 feet long, and consists of 4 rollers in a frame, which is moved by a hydraulic cylinder like the pusher of the Fritz

blooming train. The table has to be low to run under the "spools" which carry the piece to the finishing train.

The finishing train is a stand of 2 high reversing 24-inch rolls, 4 feet 9 inches long. The remarks on the constructive features of the roughing train apply equally to this train. The train is coupled direct to the engine which runs at 100 revolutions maximum; and a carrying roller on either side is driven by a belt from the roll necks. The tables consist of a railway on either side, upon which are 8 traveling rollers or spools 8 feet apart, which roll back and forth 6 feet between stops, as the rail comes upon them. The tracks consist of double headed rails lying on their sides; the inclination is that of equilibrium; the rollers throw the piece well out and a slight pressure will start it in. The spools on the front side are 5 1-2 feet long; on the back side they are but 4 feet, so as not to receive the finished rail; this drops on the driven floor rollers which carry it to the saw.

The ingots are charged and drawn at what we should call a high heat, but not too high for good steel, having plenty of manganese.

There are 7 grooves in the blooming rolls, though the first is not used. The screws are not worked. The piece goes twice through the second groove, being quarter turned on the back side, and once through each of the 5 other grooves, being quarter turned on the front side. It finishes 7 by 8 inches. The first reduction is 2 inches and the others average 1 inch.

The men are one tongsman on each side, who turn the piece without the aid of hooks, and a boy who runs both the table engine and the clutch, to bring the bloom carriage back. The back tongsman easily keeps the piece going, until it gets upon the bloom carriage. The roughing table boy then works the bloom carriage clutch where the carriage stops,

the bloom rolls off upon the roughing table and straight through the train without stopping.

An inspector behind the train watches and sometimes turns over the blooms; badly cracked blooms he pulls off the carriage; these are cold chipped, reheated and swung on to the carriage to go to the roughing train. When blooms come slightly cracked from the blooming train, they are sometimes stopped and hot chipped by hand. The roughing rolls take a 7 by 8-inch piece, and there are 6 passes of which the last begins to form the stem. There are two passes on the flat of the flange. The piece is quarter turned once on the back side and twice on the front side. There is a number of spare grooves arranged to rough every pattern of rail made, so that these rolls are not changed until they are too much worn for use. The 26-inch rolls at 52 revolutions (after much experimenting), throw the piece just far enough out on the rear table so that the inward movement of the table throws it again into the rolls. Of course the piece sometimes misses entering, and has to be adjusted by bar and tongs. The men at the roughing train are, one barman and one tongsman in front, one barman and one tongsman behind, and the table boy. There are no hooks; the turning is skillfully done by the front tongsman, while the piece is falling; the turning in the rear at the last pass is aided by the barman, who does little else except work the table lever. After the piece has passed the last time from front to rear of the roughers, the transfer table is moved in front of them: it receives the piece and drops it on the spools in front of the first finishing pass. There are 5 finishing passes all on edge, the piece being turned over in front and rear after each pass. This is because the grooves are all in the bottom roll. Double collars allowing the grooves to be alternately in the top and bottom roll, so as to keep down the fin, would of course prevent the necessity of turning over the piece.

There are a tongsman and hooker in front, and a tongsman and hooker behind. The piece almost feeds itself; and is not lifted; turning brings it right to enter the next groove. Rails of 56 to 70 pounds receive 18 passes from an ingot averaging 11 3-4 inches in thickness.

The persons employed at the three trains are:

	MEN.	BOYS.
Blooming	2	1
Inspecting	1	0
Roughing	4	1
Finishing	4	0
Foreman	1	0
Total	12	2

This is superior to our best practice which requires at least 4 persons at the blooming train, 10 at the rail train, and never less than 16 men to handle and reheat the blooms between the blooming and rail trains; also a foreman and spell hands, say 36 men.

The output has been: Flange rail, 58 pounds per yard, rolled in 3 lengths of 21 feet each, output averaged 2,064 tons per week of 11 turns, or 345 bars 63 feet long (1,035 rails), weighing 187 1330-2240 tons per turn; bull head rails, 70 pounds per yard, rolled in two 24 feet lengths 2.761 tons per week of 11 turns, or 251 tons per turn. The waste and ends are stated to be 6½ per cent on the ingot. The number of second quality rails is said to be under 1 per cent. The analysis of borings from three rail ends, taken out of the pile at random, are as follows:

	No. 1.	No. 2.	No. 3.
Carbon	0.35	0.34	0.34
Phosphorous	0.059	0.053	0.044
Manganese	1.01	1.02	0.97

It is stated that Wilson, Cammell & Co. contracted for *all the labor* to make a ton of rails, from the pig iron piled in the yard to the rails loaded on the cars, at about $2.00.

The saw is 70 feet from the rolls. The rail is carried to it on large driven rollers, which project just above the floor. The same piece is carried to the straightening plate by similar rollers. The sets of rollers are driven independently by reversing clutches, actuated by a small engine. Great steadiness of running is promoted: first, by placing the saw in the middle of an arbor, having pulleys on each end; second, by sliding the saw frame in and out in horizontal guides, having great mass and heavy bearing; third, by traversing the saw frame from a high speed shaft by means of a worm. If a single saw will cut a bar into 5 pieces (3 rails and 2 ends) at the rate of 2,000 tons a week, the necessity of 2 saws to cut a bar into 3 pieces, in order to keep out of the way of the train, in our mills is not obvious; more than this, there seems to be a positive advantage in the single saw for double or treble lengths. The last of three rails will inevitably be sawn colder than the first, and if its hot length is determined by the distance apart of the two fixed saws, its cold length will be greater than that of the first. The length to be cut off is regulated by a mechanical stop, operated at will, by a workman. The rails are not lifted from the time they leave the saws until they reach the shipping cars; the finishing machines stand successively lower; in fact, the whole plant stands on a long slope, so that stock is brought to the cupola charging floors and product is removed, by means of not very steep sidings, from the main line of the Midland Railway. There are 4 double straightening presses, 4 drills, and 2 facing machines. There are 8 straighteners working days, and 3 working nights; they get 10 shillings ($2.44) per day; also, the same number of helpers, who get 4s. 6d. ($1.10) per day. The 4 drills bore and slot 700 rails per turn.

The rail train engine is considered a good type, as far as durability and smooth working is concerned. It is wasteful

of steam, as all non-compound reversing engines must be, because they can not get expansion by a short cut off. The frame of each engine consists of 2 deep ($3\frac{1}{2}$ feet), straight, hollow pieces, extending nearly as far as below the center line, and connected at the cylinder by a hollow and deep ring (the whole cast together), against which the cylinder is bolted. The frames of the two engines are clamped by heavy lugs and rings as strongly as if cast together. The rear end of the cylinder slides as it expands and contracts on a bed plate. The journal boxes part nearly at a right angle with the center line, so as to properly take the thrust.

A matter of interest connected with this plant is the recent report of the directors of Charles Cammell & Co., Limited, Sheffield. That in order to save the heavy cost, $300,000 to $350,000 a year of railway carriage of materials inward, and of finished manufactures outward, they have resolved to acquire the rail mills of Wilson, Cammell & Co., of Dronfield, and the works of the Derwent Iron Company at Workington. They will remove their own rail mills and those of the Dronfield firm to Workington, having arrived at the conclusion that in order to make the rail business profitable, three conditions must be fulfilled:

1. The rail mills must be combined with blast furnaces.
2. These combined works must be situated on close proximity to the sea; and,
3. The blast furnaces must be situated where hematite is found, with ready and cheap access thereto.

These conditions will all be embodied at Workington. To carry out the change, $1,750,000 additional capital is proposed to be raised by shares and debentures.

One railway company alone will lose carriage payments worth $600,000 a year.

The proposal has more than a local significance, inasmuch as English manufacturers on the coast are in a strong posi-

tion for reaching the United States market, promptly and cheaply.

The Barrow Hematite Iron and Steel Works.

These works have sixteen blast furnaces, fourteen of which are built in a row, while the remaining two are half a mile distant. The weekly production of pig iron averages about 6,000 tons, but as it is always calculated that three or four furnaces are out for alteration or repairs, this does not represent the full productive resources of the works. The furnaces were originally (in 1859) 45 feet high, but they were reconstructed to their present height of 62 feet between 1870 and 1872. The average consumption of fuel is one ton of coke per ton of pig iron produced. The red hematite resmelted, is chiefly obtained from the Company's own mines in the neighborhood, at Park and at Stank. The former mine, which has been worked for over a quarter of a century, has proved to be the finest deposit in the district. The latter is the deepest of all the Furness Mines. The Furness ores average about 56 per cent of metalic iron, and it is valued for its metalic richness, as well as for its freedom from phosphorus and sulphur, of which ingredients it contains only fractional quantities. In smelting the Furness hematite ore, about 7 cwts. of limestone is used to the ton of iron made. The blast is heated to a temperature ranging between 900 degrees to 1,000 degrees Fahrenheit. The furnaces are each filled with six tuyeres. The boshes of the larger furnaces are 21 feet, and of the smaller ones 17 1-2 feet.

The blast is heated partly by Cowper's and partly by Gjer's stoves. There are three beam and sixteen grasshopper blast engines. The three beam engines are compound, with blowing cylinders, two of 100 inches, and one of 110 inches in diameter, and a stroke of 9 feet. With the exception of the building that contains the latter engines all the engine houses

are built parallel to, and at the back of, the furnaces. The hoists are inclined planes, worked by special engines. For the fourteen furnaces there are sixteen inclines, each with a separate pair of engines, the cylinders of which are sixteen inches in diameter and the stroke 2 1-2 feet. The furnaces are fitted with the bell and hopper apparatus, in order to utilize the waste gasses, which are sufficient to heat all the boilers and hot-air stoves without any other fuel.

The Steel works are parallel to, and about 200 yards dissant from the Iron works, on the pig-bed side. The Furness Railway runs between the two departments, and the rest of the intervening space is occupied by sidings, filling sheds, and a wrought iron bridge spans the whole of the railway and connects the different departments. The Iron works are situated on the shores of the Walney Channel, into which the slag is tipped. The quantity of the latter is so enormous, that a considerable area of land is annually reclaimed, so much so, that several of the furnaces and many of the lines of railway are built on reclaimed land.

In the space between the iron and steel works a block of coke ovens has been built on the Coppee system, now so much adopted on the continent. The group consists of thirty ovens, 30 feet long by 18 inches wide. The steel works are contained in three parallel erections, connected together, from 85 to 105 feet in width, and 735 to 875 feet long. Over 3,000 tons of steel, by the Bessemer process, are made per week. There were formerly 18 converters, but as this part of the works has undergone reconstruction, the number has been reduced to eleven. The accessory machinery embraces two cogging mills, three rail mills and one merchant mill. Rails constitute the chief branch of manufacture, but considerable quantities of tyres, fish-plates, axles and forgings are also made. The converters are placed in the North end of the buildings. The blowing engines are a short distance off, in a

separate building. The horizontal engines have 48-inch diameter blowing cylinders, 36-inch diameter steam cylinders and 5 feet stroke. Side by side with these is the usual arrangement of pumps for working the hydraulic cranes. An adjoining house contains a pair of vertical condensing blowing engines with 54-inches diameter blowing cylinders, 40-inch diameter steam cylinders and 5 feet stroke. The pressure of the blast in the converters is from 21 to 25 pounds per square inch, and the average time of blowing is 20 minutes. Formerly the pig-iron was remelted; now, the molten iron is brought direct from the furnaces in ladles on a specially arranged wagon, and though the molten metal has to travel nearly two miles to get round by a junction, no difficulty is experienced from any appreciable lowering of its temperature. The locomotive brings four charges at once, two in each ladle, and by means of raised sidings enters Nos. 1 and 2 sheds on a level with the converter's tops. The charge is conveyed into the converters by means of cast iron runners. Occasionally a small quantity of Swedish pig-iron is added to the charge. After the blow is concluded, the usual amount of Spiegeleisen is poured in. There are 4 cupolas for melting the Spiegeleisen. The converters vary somewhat in size but are mostly 16 feet in height, 8 1-2 feet inside diameter, and have a nominal capacity of 10 tons. Each pair is placed in respect to one another at such an angle that if necessary both can pour their contents into the same ladle. The ram to which the ladle is attached is in the centre of the pits. It revolves on its own axis and rises by hydraulic pressure. When the ladle is filled, the ram is raised and turned around, and the steel runs from the bottom of the ladle, either into separate ingot moulds, or by preference, into a hollow standard which resembles on a large scale, the runner of a casting. Hydrostatic pressure causes the molten metal to flow through horizontal channels made of perforated and specially

arranged firebricks, and to rise through the bottom into four, six or eight moulds arranged in two rows. By this means, with one opening of the valve of the ladle most, if not all, of the ingots from that particular blow are cast. In the Bessemer department, hydraulic power is solely used for working the cranes, turning the converters, etc. This power is derived from three steam engines, each having 18 1-4 inch diameter cylinders 3 feet stroke, driving five hydraulic rams varying from 3 to 5 inches in diameter.

The steel ingots are taken from the Bessemer department to the Siemen's reheating furnaces. The latter are supplied with gas from 72 producers. The method of charging the producers is mechanical. About two tons of coal slack per day is required for each generator.

From the main gas tubes branch tubes lead to the 46 furnaces employed in reheating the ingots and blooms. The cogging mills are designed to be automatic and to require a minimum of manual labor. The mills are connected to a pair of beam engines and are driven by a train of wheels arranged for reversing, but detached from each other. The reversing gear consists of a hydraulic cylinder, coupled to a lever and an ordinary clutch. The rolls in one mill are 30 inches and in the other 36 inches in diameter. The blooms on leaving the cogging mills, pass by self acting rollers to a hammer to be cut into two or three pieces as required. The mill department contains three rail mills, a merchant mill, and a tire mill, and 2 of the rail mills are three high and driven by condensing beam engines with cylinders 42 inches diameter, and 6 feet stroke. The rail mills are speeded 1 to 2 1-4, making 61 revolutions per minute. The rail mill trains are 26 inches diameter rolls, consisting of three roughing rolls, with 7 grooves. These grooves are not all used at the same time, five or six grooves in each set of rolls being generally found sufficient. Rail up to 100 feet in length

and of very difficult sections are rolled in these mills. Attached to the roughing rolls in each mill is a hydraulic lift for the purpose of raising the bloom, after passing through the grooves in the bottom rolls to those in the top rolls. The third rail mill is a very powerful reversing mill consisting of a single set of rolls, driven by a pair of horizontal engines, which make 100 revolutions per minute, the cylinder being 42 inches diameter, with 4 feet stroke. Self acting gear carry the rails to the saw in each department, and from the saw to the straightening presses, punching presses, drilling and planing machines in the usual manner. In and about the works there are many lines of railways and numerous buildings. The engines in the various parts of the works, which aggregate 9,000 horse-power, require 150 boilers.

West Cumberland Iron and Steel Company.

The Works of the West Cumberland Iron and Steel Company are situated on the coast of Cumberland, close to the town of Workington.

They consist of 6 blast furnaces, 70 feet high, which are served by 4 sets of firebrick, and 1 set of cast iron stoves. There are two pairs of blowing engines, and a single compound beam engine. The larger pairs are condensing beam engines, having 44-inch diameter steam, and 96-inch diameter blowing cylinders with 8 feet stroke, running about 20 strokes per minute. The other engines are of the vertical Cleveland type, with steam above the blast cylinders. Most of the iron is taken in a molten state direct to the steel works, a large tunnel having been driven parallel and close up to the furnace, so that the iron can be tapped at once into the ladles or run down the pig-bed, if necessary.

At these works Mr. Snelus applied the system in use there, for conveying the molten pig iron from the blast furnace to

the converters. In devising this plan he started with the conviction that it was desirable: 1st. To construct a ladle and carriage that could be moved about with safety and celerity without being an undue weight; that the ladle should be placed in the most secure position upon its carriage; that it should be easily tipped for pouring out the metal, lifted out with facility when it required to be changed; and that the man in charge of the ladle should be in a good position for turning it over, not only to see well what he was doing, but to be out of danger from splashes of metal. 2d. That all turntables and lifts should be avoided. 3d. That in order to produce the utmost economy the ladle should be brought as near as possible to the blast furnace so as not to cool the metal or have more scrap than necessary, and that the metal should be poured directly from the ladle into the converters, to avoid the cost and waste of runner making. The carriage and ladle, lined ready for use, weighs under 10 tons. The converters are arranged according to the usual English plan, facing each other, and a staging has been thrown over the pit between the two converters. The distance between the blast furnace and converter is about 1050 feet, and on a comparatively direct line from one point to the other. In order to bring the ladle as close as possible to the furnaces, a cutting was made through the pig-beds in front of the tap holes, and in order that the pig-beds might not be curtailed, the cutting is made sufficiently deep to be covered for casting purposes. In practice the iron is tapped from the furnace into the ladle, about 3 tons, 10 cwt. from each furnace. This is done to ensure as far as possible a uniform charge. Five minutes often suffices to tap both furnaces and to get the charge of metal, and in less than 5 minutes it can be weighed, taken to the converters, and poured into the vessel.

The arrangements are such as to produce the minimum

amount of scrap and scull, and the yield, in consequence, is increased.

One ladle lasts from one to two hundred casts before the scull needs to be taken out, and even then, it is only the loose coating and not the brick lining of the ladle, that wants renewing.

The practical results obtained in a fortnight's time are stated by Mr. Snelus to have been :—

Total metal used	1033 Tons.
Ingots made	887 Tons.
Ladle Scull Iron	14 $\frac{1344}{2240}$ Tons.
Iron Scrap, cleansing of ladle	1 $\frac{336}{2240}$ Tons.
Steel Scraps of all kinds	14 $\frac{784}{2240}$ Tons.
Yield of Ingots	85 8-10 per cent.
Waste	14 2-10 per cent.
Iron Scull Scrap, say	1 1-2 per cent.
Steel Scrap of all kinds	1 1-2 per cent.
Leaving absolute waste, about	11 per cent.

A careful system of analyzing the iron from each furnace daily, and mixing it, so that the silicon is kept very regular, is followed, and the steel is consequently very uniform in quality. The steel works consist of two Bessemer pits with a pair of 7 1-2 ton vessels in each, blown by a pair of horizontal engines. The steam cylinders are 40 inches diameter, and the blowing cylinders 54 inches diameter, stroke 5 feet. An independent condenser has been added to the engines. The pressure of the blast is 25 pounds to the square inch. The hydraulic power is obtained from a double-acting pump with 8 inch ram and 8 feet stroke. It runs only 6 or 7 strokes per minute to perform all the work. There is no fly-wheel. The power is regulated by an accumulator, the ram being 30 inches in diameter and having a stroke of 24 feet. The working pressure is about 500 pounds per square

inch. The product from the converters amounting to nearly 80,000 tons of ingots in the year, is worked up into rails, billets and forgings. The ingots are all made heavy enough for 4 or 6 rails, and are taken hot to the rail mill. After a slight soaking in Siemen's heating furnaces, they are cogged in a cogging mill with 34 inch rolls, driven by a pair of reversing engines. Two men do all the work at the rolls, as the ingot is moved in and out by machinery. From the cogging rolls, after being sawn in two, the bloom is taken to the reheating furnaces, and is then rolled off into a double rail by a pair of reversing engines. These are compound and condensing. They have a 3 feet 3 inch stroke and run at a high rate of speed, often up to 90 strokes per minute, during the last passes of the rail. These engines were originally used in Her Majesty's frigate the Liverpool. When this vessel was being broken up the company bought the engines, and they were compounded by adding high pressure cylinders. At the same time the bed plate, connecting rods, etc., were lengthened so as to get a better driving angle. In addition to the rail mill referred to, there are also a 23-inch pull-over mill, for light sections and a couple of 24-inch plate mills driven by a pair of engines, but reversed by clutch arrangements. The plate mills have made 400 tons of iron plates per week, but are now exclusively engaged on steel plates.

At the iron and steel works there are 48 steam boilers, 24 of these being of the double flued Lancashire type with steel flues, five being entirely of steel. The latter have been in use some time and have given entire satisfaction. Good water is obtained from a pumping establishment about a mile up the river Derwent, where a couple of horizontal pumping engines are located, each capable of pumping about 2,000 gallons per minute into the reservoir, 120 feet above the river. Altogether the works use about 3,000 gallons of

water per minute for boilers, condensers and tuyeres, but half of this is conveyed into an extensive series of cooling channels, about 1 1-8 mile long, and is used over again. There are 52 engines on the works, that work up to about 7,000 indicated horse power.

The iron ore employed at West Cumberland is obtained from the Cleator Moor mines; the coal and coke from the companies' collieries about three miles from the works; and the limestone flux from the quarries belonging to the firm at Brigham, about eight miles up the Derwent.

The Rhymney Steel Works.

The Rhymney Steel Works are among the latest, as the Barrow were among the earliest works of the kind erected in the United Kingdom. The plant having been erected for the purpose of converting old iron works and adapting them to the manufacture of steel, the arrangement was somewhat controlled by the situation of the blast furnaces, it was intended to use for the process, and also by the extent of ground available. It was erected for the purpose of making steel by the direct process—that is, by taking the molten iron direct from the blast furnaces and submitting it to the process of conversion on the Bessemer system, instead of running it into pigs and then remelting them in an air furnace or cupola, the favorite method, until very recently. More uniform results being obtained by mixing the produce of two or more blast furnaces, this plan is followed here with the means of taking a further supply of iron, when required, from the cupolas (two in number) which are situated alongside the subway leading from the furnaces to the steel works; they are used for remelting the iron made and run into pigs on Sunday, and at such other times as the steel works may not be in operation, care being taken to use such iron in the cupolas as will correct any irregularity in the iron

taken from the blast furnaces, and thus secure the desired regularity in quality.

The iron is run from the furnace into a ladle standing on a railway in the subway, and is drawn by a small locomotive engine up a gradient of 1 in 50. The carriage and ladle now stand on the floor of the converter house, and as they are still below the level of the converters, the ladle full of metal is lifted from the carriage by a twelve ton hydraulic crane and poured direct into the converter, which is then turned up and the blow commences; this lasts from 15 to 20 minutes, with a blast pressure of 25 pounds upon the square inch. After the blow the same crane conveys the spiegeleisen direct from the cupola to the converter. An empty casting ladle suspended on the other side of the crane is now swung round to receive the steel and transfers it to the center casting crane, which is then turned towards the pit, leaving the charging crane and converters clear from observation and at liberty for the next blow, which can commence at once while the casting is being proceeded with.

Within the radius of No. 2 ingot crane is placed a monkey for knocking out any ingot which may stick fast in the moulding; the tup of this monkey is raised by a chain led from a hydraulic crane near the spiegel cupolas, which crane also lifts the spiegeleisen and coke. The "stickers" are thus dealt with without delay, preventing the unsightly accumulation of "stickers," which must take place where appliances for knocking them out are not easily available.

The converters, 7 tons capacity each, are side by side, the "American Plan." The usual practice in Great Britain has them *vis a vis*, thus subjecting workmen, when repairing, to the annoyance of sparks from the other vessel.

The Company, in their report for the year ending March, 1882, show a profit of £20,000, but the directors have not recommended any dividend for the second half of the year.

CHAPTER IV.

METHODS.

FOREIGN WORKS CONTINUED — THE ESTON STEEL WORKS, ENGLAND—THE STEEL COMPANY OF SCOTLAND, LIMITED—J. COCKERILL ET CIE STEEL WORKS, BELGIUM.

The Eston Steel Works.

In 1877 Messrs. Bolckow, Vaughan & Co. opened at Eston, in Cleveland, one of the most complete and admirably arranged steel making establishments in the world. The site of these works extending over 100 acres of land, adjoins the Darlington Section of the Northeastern Railway, and abuts upon the private jetty of the firm, whence the ores are delivered and the finished article shipped without any cost for freightage or other dues. The ore is carried along an overhead railway and is emptied into huge bunkers immediately behind the furnaces. The bunkers are divided for the separate storage of limestone, ironstone and coke, and are built of strong timber, with equally strong iron supports. They are fitted underneath with valves, which enables the raw material to be emptied into the barrows, without any manual labor other than that of simply opening and shutting the valves, which are placed underneath the floor of the bunkers at the height of about 5 1-2 feet from the ground. After being filled these barrows are wheeled to the hoists, which are worked by water balances with a break wheel at the top.

The water is pumped by ordinary pumping engines into a tank placed at the top of the hoists. Three barrows are carried up at a time, the load being about 1,700 pounds. The water actuating the hoist is obtained from the Eston mines belonging to the firm and it runs in an open stream down to the steel works, distant 2 1-2 miles.

There are nineteen blast furnaces immediately surrounding the steel works, and hot air stoves each having 2,000 square feet of heating surface and giving a temperature of 1,100 degrees to the blast are attached to the furnaces. A 20-ton machine is provided for the purpose of weighing the iron as it comes from the blast furnaces, and the laboratory is placed close by the machine, so that the molten metal can be taken from the ladles and sampled and analyzed without loss of time. It is not the custom to take samples of each cast, as it is believed that the iron will be kept regular otherwise.

The converting house is divided into two departments, the basic and the hematite, each containing four converters in a row, the basic converters being nominally ten tons capacity each, and the hematite five tons. The acid converters are to be changed to basic, and this firm will have 8 converters working on the basic process. The vessels are placed at greater distances apart than is common in our American Steel plants, with the advantages of greater accessibility and the greater room on the platform for charging and other necessary operations. There is one ladle crane to each pair of converters, not top-supported, as in our home works, but balanced by a counter weight. It has the three motions of lifting, moving also around a circle, and carrying the ladle out or in, from or toward the centre, all controllable by hydraulic machinery. Its lift is so high that the ladle can be lifted above the ingot molds when these are standing on the ground level, thus enabling the deep pit to be dispensed with, and greatly facilitating the placing of the ingot molds.

The pig metal used in these converters (both basic and hematite) is all tapped directly from the blast furnaces, and is brought in ladles to the steel works, hoisted by a hydraulic lift to the railway track on the platform behind the converters, and it is then run on this track to the vessel which is ready for it, and tapped through a short runner directly into the vessel, into which the basic additions and a few crop ends or other pieces of scrap have already been placed.

The blow lasts about twenty minutes; the converter is then turned back toward the platform, and a sample taken out and tested by hammering out, cooling, and breaking, to determine whether the purification has been complete. When this is done, either with or without a few seconds of extra blowing, the steel is poured into the crane ladle where it is mixed with the spiegel which has been tapped into two small ladles from one of four cupolas standing together on the platform.

The production does not seem very large in comparison with that of our best works, (only 2,500 tons per week for four converters) but no attempt is made to run each converter to its utmost capacity the whole time, as in America. Two of the four converters are always idle, but in readiness to be used as soon as the other two are stopped for repairs. The working force of men is only large enough to keep two converters at work, and the men at twelve hours per day instead of eight, as in some of the American works.

Throughout the works care is taken to avoid working below the floor line. This arrangement represents a considerable economy with the customary Bessemer process of casting the ingots in pits, seeing that the expense and loss of time incurred in lifting the ingots out of the pits is avoided.

Here the technical and commercial success of the basic process is unquestionable. The mechanical difficulties have been successfully surmounted. The works have been in suc-

cessful operation on this process for nearly two years and the basic converting department gives less anxiety and trouble than any other department in the works, and proves that the process is in every sense past the experimental stage. After coming from the converters the ingots of steel are heated in Siemen's regenerative furnaces, of which there are a large number, covering about 2 acres, indicating that the work will not be delayed from want of sufficient heating capacity. There are 2 large 2-high blooming mills for blooming the ingots from 15 inches square down to 7 inches square. The ingots are handled by hydraulic power, and are rolled without any other manual aid than that supplied by the engineman who works the cranes and rams. These blooming mills have 40-inch diameter rolls, driven by very large double reversing engines, which are geared down 3 to 1. Each engine has a set of rolls on each side to prevent any stoppage by breakage or any other reason by which one set of rolls may become incapacitated.

The ingots, after blooming, are generally not sheared into rail lengths, but are at once taken to the 2-high reversing rail mill, which rolls 3 or more lengths of rail at once, which are then sawed to lengths by the hot saws.

The rail mill is furnished with 26-inch rolls driven by large reversing compound engines. In reference to the quality of the steel made at Eston, a table of 51 consecutive blows or heats, shows that the variation in carbon by color tests of this whole lot was only between .30 and .40, and in phosphorus only between .04 and .08.

A ball of 1,120 pounds, falling 15 feet on the finished rail, bearings 3 feet 10 inches apart, produces deflections, varying only from 1 7-8 to 3 1-8 inches in a constant length of 24 feet. If this regularity of product obtains through 51 consecutive heats, there can be no doubt it can be duplicated whenever desired, as the phosphorus in the finished product is

entirely within control of the operator. This elimination of phosphorus to the last traces depends upon the afterblow and the amount of iron which is wasted in order to make sure of such elimination. When steel rail is wanted to contain not more than .10 P., the afterblow is not carried to such an extent as when boiler plate is wanted, with below .05 P., and in rail steel, therefore, a variation in P. of from .02 to .08 or .10 is quite allowable. Upon this fact the practical and uniform elimination of phosphorus down to below .05 depends the future of the manufacture of the finer steels in the United States. Especially crucible steels, and to Bessemer and open hearth steels for boiler plates, rivets, stay bolts, and fine steels for stamping, tin plates, etc. In crucible steel manufacture at present the raw material imported is Swedish wrought iron bars, which are exceedingly costly. Their chemical peculiarity, upon which their whole market value depends, is *low* phosphorus and *low* silicon.

A basic Bessemer works in the United States making steel for boiler plates, or such like purpose, containing KNOWN QUANTITIES of phosphorus P. .01, P. .02, P. .03, etc., and all necessarily very low in silicon, the SCRAP of these works thus graded, is the very best material in the world for crucible steel, and the best material for the open hearth process to manufacture into spring and other high-carbon, low-phosphorus, and low-silicon steels. So in regard to open hearth steel boiler plates and other very soft steels. The materials now used are the best extra low phosphorus Bessemer pigs largely imported from England and Sweden for the purpose, Republic or Spanish ores, Chateaugay or other Champlain blooms, or pig iron dephosphorized by some expensive process, such as Krupp's or Bell's washing process or by ordinary puddling. However obtained, these raw

materials are all expensive. If the open hearth process for the manufacture of soft steel is to live and prosper in competition with the basic Bessemer process, its raw materials must be cheapened, and no way is so likely to cheapen it as the introduction of the basic process, and with the basic steel scrap.

As an illustration of profits at Eston, the last annual report of Bolckow, Vaughan & Co. may be quoted from. The report says:

"Your directors have pleasure in submitting herewith the "company's balance sheet and auditor's report for the year "ending December 31, 1881.

"Having regard to the low prices ruling for pig iron dur- "ing the second and third quarters, and the unsatisfactory "condition of the coal trade over the whole of the past "year, the directors feel assured that the results obtained "will be considered satisfactory to the share holders. The "amount of profit available for distribution is £305,- "806 12s 5d." This is nearly $1,500,000, but this amount "available for distribution" does not represent all the profits of Bolckow, Vaughan & Co. in 1881.

The report adds: "The plant and machinery have been "kept in an efficient state, and several important repairs and "improvements have been made and charged to revenue "account." This means that the value and effectiveness of their works were increased last year, as a basis for future profits, and that this was done in addition to setting aside $1,500,000 for distribution.

For the six months ending June 30, 1882, the directors decided on August 25, last, to pay an interim dividend at the rate of 7 1-2 per cent per annum.

The capital of this company, which is already £3,507,- 360, is about to be increased to £3,857,360, to enable the

directors to meet their greatly extending business, and to allow them to proceed with the development of the salt deposits which underlie a considerable extent of their property in Cleveland. They propose issuing the new capital of £350,000 to the extent of £250,000 in ordinary shares of £20 each, and the remaining £100,000 in 5 per cent preference shares of the value of £20 each.

The measure of the profits which iron and steel manufacturers should in equity receive must, of course, vary according to circumstances, but concerning the general proposition that large profits are necessary, it may be asked, how else can large manufacturing enterprises be built up and employment be given to large numbers of people? Large profits are needed to pay for extensions to enterprises originally small, and to provide improvements in methods of manufacture which the progressive spirit of the age, and the fierceness of competition are constantly suggesting. In no other way could capital ever have been accumulated to equip and sustain the great manufacturing enterprises of the world. The large capital upon which millions of wheels and spindles and all other productive machinery now rests mainly, represents profits. Bolckow, Vaughan & Co. was founded in 1841, with a small capital, one of the partners contributing absolutely nothing but his skill and experience as an iron worker, and for many years its operations were conducted on a small scale. In 1850, it entered upon a more prosperous career, and its present extensive works have been created chiefly with the profits of the last thirty years. The great steel works of Alfred Krupp, at Essen, in Germany, the largest in the world, were founded in 1810, by Friedrich Krupp, the father of the present proprietor, and as late as 1848, they employed only 74 workmen. At the present time they employ 17,000 persons. The commercial value of these works and their accessories, is greater than that of

the works of Bolckow, Vaughan & Co., and yet this immense value may be said to have been created wholly out of the profits derived by one family, in two generations, from an enterprise that was originally very small indeed.

It has frequently happened in the manufacture of iron and steel, that in the course of a very few years it has been necessary to almost entirely change the methods of machinery previously employed, thus entailing great and unexpected expense. In the manufacture of pig iron, the introduction of hot blast stoves and powerful blowing engines in late years has required more money than the original cost of the furnaces to which they have been attached. In the manufacture of steel, many changes in methods have occurred in recent years, each of which has been exceedingly expensive. Some of these changes, it is true, have been of radical character, as in the introduction of the Bessemer and open hearth process, which may be classed as new industries rather than as modifications of old processes; but even these new methods of producing steel have been modified and improved by experience, while the old crucible process has been almost completely transformed by the introduction, at great expense, of gas furnaces. Years ago, in the United States, a large amount of capital was expended in the erection and equipment of mills for rolling iron rails. Many of these mills have since been abandoned or converted at considerable expense into mills for rolling iron in other forms, while others have been converted at still greater expense into establishments for the production of rails made by the Bessemer, or open-hearth process.

In the report of Bolckow, Vaughan & Co., already mentioned, the necessity for frequent changes of methods and machinery, is thus referred to: "The rapid progress of "invention connected with the steel and iron trade, necessitates the greatest watchfulness on the part of your

"directors to keep the works and plant in such a state of "efficiency as will enable them to obtain the largest produc- "tion and work, with the most economical results." Even in establishments in which new methods and modern machinery have been introduced, the annual cost of repairs to and renewals of such machinery as is in use, is ordinarily sufficient to absorb no inconsiderable part of the profits. Probably no other business is so destructive to machinery and other inanimate aids which it employs, as the manufacture of iron and steel.

The Steel Company of Scotland, Limited.—The Open Hearth Plant.

There were at the works of this company in July 1874, 6 10-ton furnaces, which produced 11 1-2 tons each per heat, and 8 5-ton furnaces which produced 6 1-2 tons per heat, and 2 more 10-ton furnaces in the same line being erected. Since the revival of trade, and especially since the increased demand for ship plates, a line of 14 10-ton steel furnaces, parallel to the first line has been built. The 10-ton furnaces make 120 tons per week each, maximum in 10.44 heats, from cold pig and ore. The 5-ton furnaces make 90 tons per week each, maximum in 13.8 heats.

The percentage (on ingots) of material, other than ore, used for four months, May 10, 1879, was:

	PER CENT.
Pig	79.64
Scrap	19.70
Scull	2.81
Spiegel and ferro manganese	2.23
	104.38

Calling the ore used 50 per cent iron, the total percentage (on ingots) of materials is 119 1-4 per cent, and the loss 16.13 per cent on the materials put in.

The rail mill has a compound reversing engine, with 2 29-inch high pressure cylinders and 2 50-inch low pressure cylinders and 5 feet stroke. It is joined directly to the rail finishing rolls. This engine is geared 2 to 1, and connected on the other side by a heavy plate train. The boiler pressure is 110 pounds, the boilers being of locomotive type. Steam is cut off at nearly full stroke by the lap of the valve, and expands only in the large cylinders. The usual revolutions are 80, but the engine has been run at 120 revolutions, indicating 2,500 horse power.

The rail train consists of 3 stands of 2-high 26-inch rolls, of which the cogging and roughing are driven by an old 34-inch by 42-inch stroke engine, geared 3 to 1. The finishing rolls are driven direct by the compound engine above described. A 13-inch ingot is rolled at 1 heat in 4 cogging, 6 roughing and 7 finishing passes, into 1 heavy rail or 2 light ones. The cogging stand has feed rollers on each side, clutch geared to the train and 2 hooks. The roughing stand has 2 spools and 1 hook on each side. The finishing stand has spools on the backside and fixed under-driven rollers on an incline in front.

The men at the train are 14, as follows:

Cogging front....................	1 hook	1 tongs	
Cogging back.....................	1 hook	1 tongs	
Roughing front...................	1 hook	1 tongs	
Roughing back....................	1 hook	1 tongs	
Finishing front..................	1 hook	1 tongs	1 bar
Finishing back...................	1 hook	1 tongs	1 bar
Total, 14 men.			

Plate Rollings.—The trains are 2 reversing trains, having each 2 stands of 26 inches by 7 feet rolls, and driven by 34-inch by 42-inch stroke engines, geared 3 3-4 to 1 1-4, steam pressure 50 pounds.

There is a short table consisting of underdriven rollers on each side; bogies are used to catch the outer end of the plate when it gets long. The rolling is pretty rapid; 5-inch, 12-cwt. slabs are rolled to 1-4 and 3-8-inch by 19 roughing and 8 finishing passes in 3 minutes. There are 10 men at the train, viz.: 2 "bars" in front and 2 behind, 2 bogie men, 2 broom men, 1 extra hand, and 1 boss. One train has rolled 23 tons per turn from 5-inch 10 to 15-cwt. slabs, to 1-2 and 5-8 inch plate. The 2 trains have rolled 450 tons per week of all sizes and thicknesses down to 1-8-inch. There is no reheating; 1-8-inch plates are rolled from thin slabs. A scraper is hung on the top roll to remove scale, and twigs are thrown on the plate before the last pass, to clean it. All plates and sheets are annealed. Some plate ingots are rolled direct, but most of them are hammered to a 4 to 6-inch thickness, at a low temperature. They then roll smooth at a high temperature. It is stated that the pock-mark in the ingot shows in the plate when the ingot is rolled direct at a high temperature. The Lloyds requirement for plates is 27 to 31 tons tenacity and 20 per cent stretch, on a specimen from each plate. The Board of Trade and Admiralty require 26 to 30 tons tenacity and 20 per cent stretch. The softest plates have carbon, 0.18 and manganese 0.50. The plate train engines are geared, because on short work the engine could not get up to speed, and would be wasteful. Directly connecting the engine to the train is no doubt better for rolling rails and other long work.

Excepting I beams, all other required shapes are rolled up to 12-inch I deck beams; these, also L.'s and T.'s, are already produced in the train rail. Foundations for trains and engines are made of concrete, excepting the pockets for the hold down bolts. The trains are set on timber bedded in the concrete.

The following is the cost of ingots for four weeks ending May 10th, '79 ; one third plate, two thirds rails.

The cost of pig was excessive, the company having some thousands of tons on hand at this price. The same pig at the then current price, $12.45, would make a difference in the cost of ingots of $1.53. $12.45 was the price of the pig used.

Description.	Weight.	Rate.	Amount.	W't per ton. LBS.	Cost per ton.
Pig Iron..................	2901.1778	14.39^{6}	41774.20	1784	$11.44
Steel and Iron Scrap.......	717.1925	13.90^{8}	9983.96	441	2.74
Scull.....................	101.1904	12.81	1304.71	63	.36
Spiegel..................	39.2016	22.77	908.61	24	$.24^{5}$
Ferro Mang................	42.2198	56.95	2448.20	26	$.67^{5}$
Ores, various..............	1085.1554	$4\ 02^{6}$	4371.	667	1.21
Sand and Loam............	....	......	143.12	......	.04
Ganister	....	......	280.14	......	.08
Coal and Dross............	2709 672	......	2786 87	1665	$.77^{5}$
Ing. Molds and Bot's......	....	......	1696.56	......	$.47^{5}$
Stoves...................	....	......	348.99	......	.08
Sundries..................	....	......	110.52	......	.02
Steel and Iron Castings....	....	......	338.76	......	.10
Brick, Fire Clay, &c.......	....	......	314.52	......	.08
Wrought Iron, Steel & W'd	....	......	52.25	......	.02
Use of Machines...........	....	......	86.50	......	.03
Wages	....	......	....	......	....
Steel Melting.............	....	......	5070.94	......	1.38
Pattern and Carpenter.....	....	......	55.29	......	....
Fitting and Erecting	....	......	187.17	......	....
Smithy..................	....	......	127.89	......	....
Foundry	....	......	121.68	......	.49
Bricklayers	....	......	485.36	......	....
Yard Labor...............	....	......	799.46	......	....
Interest, &c..............	....	......	2710.82	......	.75
Less:			76507.65	......	$20.98
TONS. LBS.					
Scull...... 100 1624 at $12.81..$290.29					
B'd Ingots, 7 1568 at 13.90.. 107.10			1397.39	......	.36
Steel ingots made, tons 3642—lbs. 1435....			75110.26	......	$20.62

The following statement shows the work per ton of ingots:

STEEL WORKS OF SCOTLAND, MAY, 1879.

Each open hearth furnace, 1st hand	$.10^{15}$
Each open hearth furnace, 2d hand	$.06^{6}$
Each open hearth furnace, 3d hand	$.06^{6}$
Each open hearth furnace, Pitman	$.06^{6}$
One producer man to each block (1 block per furnace) and 4 ash-men to 10 blocks, each	$.07^{1}$
A.—Yard contract for discharging cars of all material used, including coal, and removing slag, scrap, etc., but not ingots nor producer ashes	$.10^{15}$
B —Contract for weighing and wheeling all material to furnaces.	$.09^{64}$
C.—Ladle contract	$.07^{10}$
D. —Pit cleaning contract (not removing slag and scrap), (see A.).	03^{04}
Slag breaker, per slag	$.20^{3}$
Two locomotive crane men, per turn, each per day	1.22
Two locomotive crane helpers, per turn, each per day	$.77^{2}$

The slag is cast in one great cake and removed bodily.

Cost of 41 pounds flange rails May, 1879:

One ton of ingots	$20.62
Labor at rolls and furnaces	.65
Labor furnished	.86
General expenses	.77
Depreciation	.59
Coal and producer wages	.31
Repairs	.86
Charges	.71
Waste and miscellaneous	.98
Cost of one ton of rails	$26.35

Rolling from very thick ingots direct to plates has been introduced at the Otis Works, in Cleveland, Ohio, and at Schoenberger & Co.'s, in Pittsburg, and no doubt they have found an advantage over the issue of smaller thickness, in quality of plate, as well as in economy of manufacture.

To get plates low in phosphorus, a selection of the best brands of West Coast hematite pig, or Swedish pig, and Spanish ore is used, and it is easy enough never to exceed

.05 phosphorus, which is the highest that should ever be allowed in a good boiler plate, and less than is advisable for a plate for a locomotive fire box. Locomotive fire boxes, in England and the Continent, are rarely, if ever, made of steel, while in America some of our best railroads use nothing else. The chief reason why locomotive fire boxes are not made of steel abroad, is phosphorus. If there be any other reason, it is carbon. The neglect to keep the two elements in steel in small enough percentages, has been the causes of so many numerous failures of steel fire boxes on the other side of the ocean, causing them to be entirely condemned, while in America, close attention to this slight matter has brought the steel fire boxes into almost universal use.

The Steel Company of Scotland have done considerable work in the manufacture of steel castings without blow holes, by the use of a silicide of iron, or a silicide of iron and manganese, shortly before the tapping of the metal out of the furnace.

Very few people have knowledge of methods by which steel is almost perfectly welded. A recent disclosure is, that the steel must be very low in both phosphorus and carbon, and very high in manganese, say .05 P, 12 C, and .75 to 1.00 Mn. Such steel has been welded from scrap into a large steamboat shaft at the shipbuilding works of William Denny & Sons, Damberton, near Glasgow.

The Steel Company of Scotland have another works besides those at Newton. They are at Blochairn, a few miles out of Glasgow, in another direction. These have also open hearth furnaces, and some very large plate mills, one of which will roll plates up to ten feet in width.

The directors of the Steel Company, of Scotland, Limited, have declared a dividend at the rate of 7 per cent per annum. The dividend last year was at the rate of $5^{3}/_{8}$ per cent.

Belgium.

In Belgium there are the J. Cockerill Works, at Seraing, the Augleur Works, and those of the Societe de Selessin. The first of these has eight converters, four of which are in reserve ; the second four converters, and the third Siemens-Martin furnaces. With the exception of the product of three blast furnaces, the pig-iron employed in the manufacture of steel mostly comes from England.

The Steel works of J. Cockerill et Cie, at Seraing, are the most important in Belgium, and taking into account the mines of ore, coal and limestone, the coke furnaces and the ship yard, they employ about 12,000 men. They comprise several blast furnaces, each furnished with Whitwell stoves.

The principal dimensions of the blast furnaces are as follows :

Diameter of hearth	5.248 feet.
Diameter of bosh	16.40 feet.
Diameter of top	11.48 feet.
Total height	60 feet.
Inclination of boshes	67 1-2 degrees.
Capacity	7,942 cubic feet.

Blast engines of the special vertical type of Seraing, so well known, and of which 123 are in operation in various places on the continent, furnish the necessary blast, at a pressure of 6 lbs.

The blowing cylinders of the engine have a diameter of 10 feet and a stroke of 8 feet. The steam cylinders are on the condenser principle.

The normal number of revolutions of the engines is 13 per minute. This furnishes 14,120 cubic feet of blast, the quantity needed for the combustion of 120 metric tons of coke in 24 hours.

To the right and left of the blowing engines are situated the mixing sheds for ore, and outside of these again are the

pumping engines for the whole of the hydraulic apparatus of the establishment.

The sheds where the charges of ore are prepared, are supplied with hydraulic lifts, which raise the ore to the proper height, and allow of its being thrown into separate boxes or compartments, where a thorough mixture of raw material can be easily effected.

In front, and to the north, is placed a group of boilers, made from Bessemer steel plate, 5 1-4 feet in diameter, and 49 feet in length. They each carry a large reheater, 3.28 feet in diameter, and 49 feet in length. The boilers are heated by the escaped gasses from the blast furnaces.

On the South side the blast furnaces are situated alongside the Bessemer Foundry, which is divided into three separate compartments by a series of cast iron columns.

The first compartment comprises the pig-bed, and also receives the ladles and the hydraulic lifts, which carry the molten metal from the furnaces to the converters.

The second compartment contains the cupolas, where the remelting of the pig iron is effected when at any time or from any cause it is thought advisable to work by the old process.

The third compartment comprises the converter department. Here there are six converters, two to each pit, receiving alternately the iron from the furnace, or from the cupolas, as the case may be. The latter are furnished with hot air receivers for keeping the liquid metal hot.

Parallel with these buildings, and in the south side, are situated the blast engines for the converters, the pumps and the accumulators, having, to the right and to the left, a group of eight boilers each, of exactly the same make as those employed for the blast furnace engines.

The Bessemer blast engines belong to the class constructed as a specialty by the Seraing Works, and were designed by

Kraft, the chief engineer of the Cockerill Company. These engines are of the compound vertical type, realizing a very great economy in fuel, the consumption of coal being only 2 3-4 lbs. per indicated horse power, per hour. The length of the rolling mill is 270 feet, comprising two divisions, each 59 feet wide, and united by a row of columns 33 feet in height.

In the first division are placed six large sized furnaces, whose bottoms measure 12 by 16 feet, and are sufficient to hold the ingots needed for the two rail mills situated in the next or third department.

The first or blooming mill, has two pair of 36 inch rolls, and is worked by a reversible engine running 45 turns per minute by means of gearing. This has a separate engine for the condenser.

The steam cylinders are 32 inches in diameter, and have 4 feet stroke, the pinions being in the proportion of 1 to 2 1-2 inches.

The second or finishing mill, has two housings with 24-inch rolls, and is worked by a direct acting reversible engine, running 80 to 90 revolutions per minute. The engine has two steam cylinders, 40 inches in diameter, and acts directly on a crank from 12 to 14 inches in diameter, placed on the axis at the end of the combination.

Special condensers are applied to this engine in order to avoid the inevitable counter-pressure so prejudicial to the working of engines of this class. As a complement to the rolling mill a special rail-finishing shop is erected, containing all the most modern and improved appliances for the purpose required.

The molten metal is, immediately after it runs from the blast furnace into the tilt ladle, taken to the converters by hydraulic lifts and to the stationary bridge, on which it is carried on rails. It is weighed in a very simple manner

while on the lift by means of the indications of an ordinary pressure gauge, placed in communication with the water in the hydraulic cylinder of the lift.

No inconvenience is suffered if the iron be left an hour in the ladle, beyond the presence of a small solid bottom, which can be remelted afterwards in one of the cupolas.

In the middle of the decarburation, from 10 to 25 per cent of rail ends are added, the quantity varying according to the temperature of the bath.

A remarkable fact connected with the steel making process at Seraing is that no spiegel whatever is introduced into the converter at the end of the blow, it having been found that the iron contains sufficient manganese to render this addition unnecessary.

When the bands of the spectroscope have all disappeared, the slag is assayed in a very simple and practical manner, the end of the operation being determined simply by a color test.

The modus operandi is as follows: The blow is momentarily stopped and the converter inclined; a paddle is then introduced through the mouth and dipped into the bath. This is then drawn out, steeped at once in water, and the thin sheet of investing slag taken off and compared with a standard scale.

A lemon yellow slag corresponds to a very hard steel, containing:

	0.75 of carbon, or more.
Orange yellow	0.60 of carbon, or more.
Light brown	0 45 or carbon, or more.
Dark brown	0.30 of carbon. or more.
Bluish black	0.15 of carbon, or more.

As soon as the metal in the converter has reached the desired degree of hardness, which can be regulated at will by prolonging or shortening the blow, it is run into the moulds in

the usual way, and the ingots are taken to the forge as soon as crystalization has taken place, and before they have had time to cool.

Three very light hydraulic cranes to each pit lift out the ingots rapidly, and without difficulty. The pit itself is very wide, 33 feet in diameter, and is shallow, only 3 feet deep, and as the moulds are placed side by side, plenty of space is left for circulation in the center.

The superiority of the Seraing rail mill has been so highly appreciated by continental iron and steel manufacturers, that within two years of its being put into operation, the company received orders for five others of the same type.

CHAPTER V.

THE BASIC-BESSEMER PROCESS.

BASIC LININGS—LIME ADDITIONS—BASIC PIG—AFTER-BLOW—WASTE—BASIC STEEL—OUTPUT—QUALITY—COST—PROGRESS OF THE NEW PROCESS—ITS COMMERCIAL SUCCESS.

Serious difficulties have confronted those anxious to arrive at the truth as to the practical operation of the Basic Process, chiefly with reference to;

The method of making Basic bricks;

The repairing of Basic bottoms;

The means of producing iron that would blow both hot and pure;

The whole matter of waste:

The treatment and uses of Basic steel generally, and the extra cost in works not adapted to the Basic process.

Efforts have been made by persons, with interests antagonistic to phosphoric ore development, to prejudice the minds and bias the judgment of the iron and steel world, by the exposition of SPECIAL criticisms by accepted authority, as the results of impartial and disinterested investigation. The showing of Tunner, for instance, that the process would not be likely to pay at Kladno, in Austria, was claimed to prove that it would pay nowhere. Tunner's report was entitled to

consideration as that of an unquestioned authority, and yet he bases his showing purely upon local drawbacks. Again, certain chemists have attempted to demonstrate that if certain elements behave as they may be expected to, phosphorus could not be eliminated, unless certain different reactions were made to occur, by introducing other elements, at an expense which would render the process in most localities impracticable, etc.

Probably the most damaging criticism the Basic Process has met, emanated from Mr. I. Lowthian Bell, a few years ago, at the Dusseldorf meeting of the Iron and Steel Institute, when he made the statement that Prof. Tunner, in the report of the Austrian Commission, "Made out very clearly that the additional cost of the Basic treatment was something like 20 shillings per ton." From this started the idea that phosphoric pig must be at least $5.00 per ton cheaper than ordinary Bessemer pig, to allow the manufacturer to get out whole, without profit.

The explanation of this statement by Prof. Tunner has gradually become better understood. As one example, in a note to his remarks at the Dusseldorf meeting, Mr. Bell says: "My attention has been called to the fact, that Prof. Tunner's calculations were made in paper currency, and not in silver. His 9 1-2 florins per ton would, therefore, be equal to about 16 shillings and not 20 shillings per ton."

Likewise, it appears that Prof. Tunner's estimate was founded upon 18 per cent of waste by the Basic process and 12 per cent by the acid process. The money difference was actually but 20 cents (silver) per ton of steel. Although with different irons the "waste" varies, the average in the Basic process is really only 4 per cent instead of 6 per cent greater. We find at Creusot, and at Brown, Bayley and Dixon's that the Basic waste is but 11 per cent; at Angleur it is under 13, and at Rhurort it is 15 to 15 1-2 per cent.

Again, it will be found that Prof. Tunner charged in 64 cents per ton of steel for excess of Spiegel demanded in the Basic over the acid process. This is contradicted in the practice at Bolckow, Vaughan & Co's, where half the ordinary quantity of Spiegel is saved, a cheap, siliconized pig being substituted.

Once more, lime additions are counted in by Prof. Tunner at a cost of 56 cents per ton of steel. That a fifth of a ton of cupola burned iron cost much less than this price in most iron regions is plain, and also that is worth something as slag in the blast furnace. The estimate of cupola expenses is $1.60 to $3.20 per ton of steel and charged against the Basic process only, because white iron "might not run hot enough from the blast furnace." This is answered at Creusot and at Bolckow, Vaughan & Co's., white iron being run at both —and at the latter works certainly—hot enough for practical purposes.

Finally, the figures of Prof. Tunner included the extra cost of securing a comparatively small basic product from an old fashioned plant, without any adaptation to the new requirements of basic repairs; and there, extra costs included 96 cents for blowing, stoves, labor, interest and general expenses. Seventy cents is the amount at which the extra cost of refractories and repairs is put, and is low enough.

It should therefore appear plain, that in a PROPERLY ADAPTED WORKS specially designed for the purpose, the Basic Process, in place of costing $5.00 per ton more, is in reality cheaper in practice than the acid process. The cost of lime additions and ore excess of lining materials would approximate a dollar, but a saving might be made in the cost of both waste and recarbonizer, and some return might be expected from slag as a blast furnace material, and added to this saving would be that of cheaper pig and the profit on a better quality of soft steel.

It was quite generally predicted, when the results of the early basic experiments in England were hard, brittle and irregular steels, on account of considerable reabsorption of phosphorus from the slag and incomplete dephosphorization, that the basic process might be applied to rails and coarse work, but that what was really required in quantity was a pure, soft ingot iron adapted to boiler plates, ships, bridges, and to the manifold structural purposes; and it was asserted that the rule, that "pure products could spring alone from pure materials," was not likely, just yet, to be disproven. And when, a year later, Hoerde and Witkowitz had brought forth, by the basic process, and from pig so phosphoric that it had been abandoned for puddling, a steel which had in it more iron and less impurity than any Cumberland or Swedish Bessemer, it was then acknowledged that the new process might possibly become of limited value, as, although it did not seem capable of producing the hard steel wanted in quantity, its soft products necessarily possessed a *small* range of usefulness.

But putting aside this style of criticism, Prof. Tunner, Prof. Ackerman, Mr. Pourcel and others have scientifically explained the true difficulties in making hard steel by the basic process, and this is the obstacle: To burn out the phosphorus, blowing must be continued until every other hardening element has been eliminated. An addition of spiegel enough to theoretically restore the necessary amount of carbon, on the contrary, restores too much phosphorus. The carbon in the spiegel combines with the oxygen of the oxide of iron in the bath, making carbonic oxide, and this reduces the phosphorus in the slag, restoring it to the steel. It was not that the steel could not be hardened, but that it possessed the brittle hardness characteristic of phosphoric steel.

In connection with the Terre-noire steel casting manufac-

ture, the remedy has been discovered, and has been demonstrated by Mr. Pourcel. It was to take up the oxide in the bath by silicon—by adding a pig high in silicon and low in carbon—so that carbon subsequently added, by means of spiegel, would go into the steel instead of making carbonic oxide to reduce phosphorus ; this is the practice at Bolckow, Vaughan & Co.'s, at Witkowitz and at Montlucon, with the further economy of a saving of spiegel. At Montlucon, steel with ½ of 1 per cent carbon is regularly produced. The requirements of tire and axle steels, which are of moderately hard grades, are stated under Hoerde product, and are fully met by basic steel at these works.

It has been suggested that the basic process would be of limited value in places where 1 or 2 per cent of manganese could not cheaply be put into the pig. The offices of manganese are : First, to prevent a high percentage of sulphur in the pig. It happens that some of the phosphoric ores, most used in France and Germany, are also very sulphurous ; such is not the case with many of the highly phosphoric ores of the United States. But it has been abundantly proven that plenty of lime and hot blast will remedy the difficulty. The users of the very sulphurous Luxembourg ores, Metz & Brothers, for example, formerly put silicon 0.30 to 0.50 into their white pig ; now they put in but 0.12 to 0.15 silicon, and they also keep the silicon under 1 per cent. The large furnace of Bolckow, Vaughan & Co., which formerly produced a pig with high silicon and about 1-3 per cent of sulphur, now keep silicon down to 1.00 to 1.20 per cent, and sulphur to 0.20 or under with only 0.40 manganese in the pig. There is 35 per cent of lime in the slag of the blast furnaces. Mr. Whitwell, of Middlesboro, stated at the Dusseldorf meeting, that he had made some 4,000 tons of pig, averaging (10 analyses) sulphur 0.099, silicon 0.14, P. 2.951 and manganese 0.317, out of 1-4 Cleveland ores, 1-2 forge cin-

der to give the P., and 1-4 Spanish ore to give the manganese.

Manganese also helps to remove the sulphur in the converter.

But sulphur in higher proportions than it is likely to occur in the United States seems to do little harm. Mr. Edward Riley states that some of the very best rails have sulphur 0.10 to 0.18, and that the only objection to sulphur 0.27 was red shortness.

Manganese is useful to give heat early in the Bessemer operation ; before the burning of the phosphorous, when, as it should be, silicon is low. The large charges are sufficiently hot with about 1 per cent silicon and only 0.40 manganese.

Manganese is probably not indispensable, although 1-2 of 1 per cent in the pig is useful. This amount can be put into pig at little or no extra cost in many parts of the United States. In any works a little cheap spiegel (no matter how phosphoric) can be run into the vessel along with the pig.

It has been assumed by some experts that metal for the basic process must be so low in silicon that it can not be got hot enough directly from the blast furnace, and that the extra cost of cupola melting must be incurred. At Hoerde this was the case, but at Creusot there are no cupolas ; and although there is a little cemplaint of cool metal, the Creusot general results are as good as those elsewhere. Bolckow, Vaughan & Co. use hot blast furnace metal direct, and with some delay in transportation, but the 10-ton charges are hot enough. Mr. Snelus said, at the Desseldorf meeting, that at West Cumberland blast furnace metal would live longer than cupola metal in a ladle, and that while blast furnace metal would blow hot enough with 1.25 silicon, cupola metal needed 2.25 to 2.50 silicon.

The very important consideration of decreased output, in a plant where basic lining can not be as well kept up as acid

linings, is, of course, a serious one, and a large outlay would be necessary to make necessary changes in an existing plant, working on the acid process, to be adapted to the new conditions of the basic process.

Basic Linings.—Dolomite should have from 16 to 20 per cent of manganese in order to preserve bricks, etc., from damage by the atmosphere. It should have 4 to 6 per cent of silicon and 3 to 5 per cent of allumina and oxide of iron, to promote coherence ; much more silicon than this would impair the basicity of the slag.

Basic bricks are molded without much pressure, from raw dolomite ground to pass a 10 to 15 mesh sieve and wet with water ; they are dried in about 48 hours, at a temperature of 120° Fahrenheit, and are then burned about a week, including heating and cooling. They are set in vessel lining with a mortar of pulverized dolomite brick and 5 per cent of coal tar. Open hearth bottom bricks are laid raw in the open hearth furnace and burned in place at Creusot.

Burning Bricks.—In basic brick-making, two important economies have been developed : First—burning the basic bricks in a thin stratum on the top of a kiln nearly full of acid bricks, there being a separating layer of maganese or bauxite bricks between the two to prevent fluxing. A thick pile of basic bricks in a kiln is so thrown together as to produce many wasters, on account of the excessive shrinkage. A thin layer of basic bricks burned by themselves would require an excessive amount of fuel. Second—The regenerative gas kiln gives a larger economy of fuel ; the cooling bricks heat the incoming air for the burning bricks. This kiln also produces better bricks by means of gradual heating and cooling, and of a uniformly intense temperature while burning.

Rammed Linings and Bottoms.—Dolomite should be thoroughly calcined, at as high a temperature as the kiln or

furnace will stand, in order (first), that no carbonic acid may be left, and second, that less moisture may be absorbed ; these respectively disintegrate the linings ; third, to increase the mechanical hardness and duration of the lining ; and fourth, to promote economy by absorbing less tar than soft burned dolomite requires.

Dolomite may be hard-burned in a basic-lined cupola, with 1,800 pounds of coke per ton of calcined stone. This is a convenient and economical method.

Dolomite should be ground and used while fresh burned, so that it will have little time to absorb moisture.

Rammed lining and bottom stuff should be mixed in a mortar mill with from 10 to 13 per cent of coal tar which has been boiled to expel its ammonia and water. This mixture will stick pretty well to the burned skin of a lining or bottom. The volatile parts of the tar soon burn away, leaving the particles of dolomite bound with a neutral and perfectly refractory coke-cement.

Bottoms of the above dolomite and tar mixture should be burned at a low red heat long enough to coke the tar, and while burning, they should be held on all sides in an iron mould, which will prevent their swelling, and will give hard surfaces. Bottoms for tuyeres should be moulded around hollow iron dummy tuyeres, for the same reason.

Ordinary acid tuyeres last in dolomite bottoms nearly as well as in acid bottoms ; but dolomite tuyeres, made of calcined stone and 5 per cent of tar, formed in a split mould, and burned with the bottom, give better results. Pin bottoms, made of perfectly calcined dolomite, with 10 to 13 per cent tar, and properly burned, as above described, endure about as well as ordinary tuyere bottoms.

Ball Stuff.—A mixture of calcined dolomite with 20 per cent of tar, thrown as ball stuff, or plastered as mortar into joints, such as the joint around a bottom, or around a newly

set tuyere, becomes semi-fluid, and runs at once, if the lining is hot, into the smallest crack, where the tar quickly cokes, leaving the dolomite well cemented. Metal may run into the vessel within a few minutes after the joint is thus stopped.

Slagging of vessel noses is prevented by making the noses small to compress and increasing the temperature of the gases, and by lining the noses with the best ordinary fire-brick, separated from the dolomite lining by some neutral material.

The practice seems to be growing in the direction of rammed, rather than brick linings.

Neither rammed nor brick linings stand, so far, above 80 to 100 heats, without needing such extensive repairs around the bottom sides, that the vessel must be cooled down.

About one hundred pounds of dolomite bricks and rammed stuff are required in the average practice, per ton of steel.

The variations in the composition of pig used in the Basic process are considerable, as shown by the following table:

	Maximum.	Minimum.	Creusot average.	Witkowitz average.	Rhenish average.	Hœrde average.	Augleur average.	Bolckow, Vaughn average.	Best Mixture.
Si...	1.40	0.06	0.70	1.00	0.80	0 30	1.40	1.00	0.50 to 0.75
P...	3.00	0.96	2.30	1.60	2.00	1.75	2.00	1.75	2.00 to 3.00
S....	0.30	0.05	0.20	0.15	0.15	0.15	0.14	0.20	under 0.15
Mn.	2.25	0.36	1.50	2.00	1.10	1.00	0.70	0.40	0.50 to 1.00

As first rate steel is made from all the above mixtures, the process is elastic, and adaptable to various regions. Phosphorus should be over one per cent in order to maintain the temperature of the bath. Higher phosphorus undoubtedly

causes greater waste, but its combustion more completely cleanses the bath from other impurities. Silicon must not be much over one per cent, so that it will not impair the basicity of the slag. Manganese is useful up to one per cent, or a little over. There are very few kinds of iron which cannot be successfully used, though, on the other hand, there are some which give specially good results. The only partial exception to be made is in the case of pig iron, which contains materially over three-tenths per cent of sulphur, or over 2 1-4 per cent of silicon. But even pig of this composition can be readily treated if subjected to a preliminary desulphurizing or desiliconizing process. The dephosphorizers' ideal pig has a composition falling roughly between the following limit :

Silicon. Per cent.	Phosphorus. Per cent.	Sulphur. Per cent.	Manganese. Per cent.
.5 to 1.7	.8 to 3.	under .3	Not over 2 1-2

The chief source of the phosphoric pig, next to the phosphoric ore, is puddling cinder. Enough Bassic-Bessemer slag has been used in the blast furnace to make its economy as an ore probable. It appears to be practicable to make pig low in both silicon and sulphur, from almost any ores, by means of using plenty of lime in the blast furnace.

German Basic Pig.—The Germans have done most in the *study* of the basic process, and the requirements of the metal used for it. The chemical composition aimed at is 2 to 3 per cent of phosphorus, 2 to 2 1-2 per cent of manganese, 2.5 to 3.5 per cent of carbon, less than one per cent of silicon, and less than 0.1 per cent of sulphur. Herr Hilgenstock insists that the manufacture of such pig is the simplest and most favorable known to the ironmasters, and

that there is a great difference between producing such metal and making Bessemer pig with guaranteed percentage of silicon. All that is necessary is, to run the furnace hot. It has been urged that the phosphoric acid in the ores is difficult to reduce. While it is true that small quantities of phosphoric acid—0.2 per cent at Ilsede and 0.32 to 0.45 per cent elsewhere—are found in the cinder, and that 0.44 per cent of phosphorus has been detected in flue dust, it is nevertheless true that phosphoric acid is readily reduced at high temperatures, and that it goes into the pig. In a general way, it is safe to say that the quantity of phosphorus in the iron can be closely ascertained from the percentage of phosphoric acid in the ore. The cubical contents of furnace for the production of one ton of iron per 24 hours is only 88 to 106 cubic feet for the Basic pig, against 141 cubic feet for ordinary Bessemer, so that 100 tons per day can be run out of a much smaller furnace; and Herr Hilgenstock questions whether any increase in the size of the furnace beyond the limit of 8,800 to 10,600 cubic feet of cubical contents leads to a corresponding reduction in the quantity of coke used. As compared with the manufacture of Bessemer pig, the production of Basic pig requires 880 lbs. of coke less per ton of iron made. These statements are very important as bearing upon the relative cost of Basic and Bessemer steel, and they show that the success of the former does not entirely depend upon a difference in the price of pure and phosphoric ores.

Basic Additions.—Lime from any carbonate, suitable for blast furnaces, seems to answer. From 15 to 22 per cent on the pig—average about 18 per cent—is added. Pouring off the slag and making a third of the basic addition, just before the drop of the flame, may save lime and bottoms, but it will cause delay.

Lime must be preheated, especially if the charges are

cool, as they are generally likely to be. Heating the limestone to a bright yellow, in a cupola, with 10 to 15 per cent of coke, and then running it by gravity into the vessel, saves previous burning, and is an economical and expeditious method. Heating lime in the vessel, is, of course, incompatible with a large out put.

Blowing in lime seriously retards the blast and cools the charge.

The time of the basic blow varies, as does that of the acid blow, according to tuyere area, blast, pressure, or other causes. Together with the stopping for tests and the after-blow (from 2 to 5 minutes), it is the longer by a few minutes. But it need not be the longer in improved practice, because tests are, already largely, and are likely to be together, dispensed with when mixtures are uniform ; and a greater blowing power and quicker blowing are generally recommended by experts, and are readily provided.

Tuyeres, with 5-8 to 3-4 holes, appear to last quite as well as our 3-8 hole tuyeres ; and with a given pressure of discharge, they reduce the strain on the engine considerably. The enormous friction of this volume of air passing through long, small holes is simply waste. The same area of larger holes does not, indeed, distribute the blast so much, but it gives a stronger blast, and so produces the desired mechanical effect as completely.

Before the metal (which may be either employed direct from the blast furnace without intervening remelting, or, if for any reason this is not convenient, may have been remelted in a cupola) is run into the converter, from 15 to 18 per cent of its weight of common well burnt lime is thrown into the vessel. The metal is then introduced and the charge is blown in the ordinary way to the point at which it is stopped, that is, till the disappearance of the carbon as indicated by the drop of the flame. The dephosphorizing process requires,

however, to be continued for a further 100 to 300 seconds, this period of so-called afterblow, which would be prejudicial both to quality and yield in the ordinary process. The termination of the operation is shown by a peculiar change in the flame, and checked by a sample of the metal being rapidly taken from the turned down converter, and flattened under the hammer, quenched and broken, so as to indicate by its fracture whether the purification is complete. A practical eye can immediately tell whether or not this is the case. If the metal requires further purification, this is effected by a few seconds further blowing. The operation is thus, as will be seen, but little different from the ordinary Bessemer process. The differences that have been indicated, viz.: The lime lining, the lime addition, and the afterblow are, however, sufficient not only to enable the whole of the phosphorus, which would be otherwise untouched, to be completely removed, but the silicon, of which inconvenient and ever dangerous quantities are occasionally left in the regular Bessemer process, is also entirely eliminated, while at least 60 per cent of any sulphur also untouched in the ordinary process, which may have been present in the pig, is also expelled. It is found, too, that the once dreaded phosphorus is of most substantial assistance in securing, by its combustion, the intense heat necessary for obtaining a successful blow and hot metal. If it is desired to produce ingot iron, or a metal differing only from puddled iron by its homogeneity and solidity, the usual recarburizing addition of spiegel is omitted or replaced by one-half per cent of rich ferro manganese, which represents a considerable economy in the manufacture of harder steel. The phosphorus is oxidized by the blast, forming phosphoric acid, which, finding itself in presence of two strong bases, oxide of iron and lime, unites with the latter of them to form phosphates of lime, which passes into the slag.

Waste due to the after-blow, is no greater, at Creusot, than the waste in the ordinary process. The waste at other works is from 2 to 4 per cent greater; it averages about 15 per cent, not including the iron which slops out of too small vessels. The cost of waste would usually be less with phosphoric irons at current relative prices. A waste of 16 per cent on a $16.25 iron would cost the same as a waste of 13 per cent on a $20.00 iron.

Spiegel is now used in less quantity in the basic than in the acid process, thus not only economizing material, but leading to the production of a purer steel, as follows:

A highly siliconized pig is substituted for half the usual amount of spiegel. The silicon takes up the oxide in the bath, so that the carbon in the spiegel afterwards added, will not be oxidized into carbonic oxide, which would reduce the phosphorus in the slag. And all the maganese in the spiegel goes into steel.

The release of phosphorus from the slag is largely prevented at Bolckow, Vaughan & Co.'s, by using ferro-silicon before spiegel. It was known that the cause of the release was the reducing action of the carbonic oxide on the phosphoric acid in the slag, and that this carbonic oxide was produced by the action of the carbon, in the spiegel upon the oxide of iron dissolved in the bath. Some means were wanted to reduce this oxide of iron without producing carbonic oxide. After some trials the system so important in making the Terrenoire solid steel castings was adopted. Eight per cent of a pig containing 2 per cent of silicon is added after blowing.

This puts in the bath 0.12 to 0.15 silicon, all of which is used in absorbing all the oxygen in the oxide of iron. Then 3 1-2 per cent to 20 per cent manganese spiegel is added, which gives about 0.40 manganese in the bath, all or nearly all of which remains in the steel.

Another important result of this treatment is that more carbon can be put in the steel; all the carbon added will remain, because the oxygen in the bath, which would otherwise take it up, has been removed by silicon. At these works, steel is regularly made with C. 0.50.

Hard steel hardened by carbon, and not also made brittle by phosphorus, may be produced by the basic process, in the manner above stated. After the oxygen in the bath is taken up by the silicon, any added carbon will go into the metal, and will not get made into carbonic oxide to reduce phosphorus.

Slag is generally poured off before the addition of spiegel, to still further prevent the restoration of its phosphorus to the bath. This operation causes but slight delay; probably no more than slowly pouring it into and over the side of the ladle. As the slag is very voluminous, including 16 to 20 per cent of lime, as well as the ordinary impurities, the plant should be arranged to catch it in the cars as it pours from the vessel and from the ladle, and to draw the cars to the dump by a direct and uninterrupted road. Breaking this slag up and shoveling it out would be quite impracticable.

Sound casting is due to making the steel hot, and teeming it as cool as possible without sculling; also, to slow pouring by means of a small, smooth stream. Large ladles must be emptied through a fore-hearth or funnel, and the plant must be so arranged that casting can be going on all the time. These precautions are particularly necessary for basic steel, which is apt to be a little "rising."

At Creusot, bricks have been abandoned, and the vessel is lined with a mixture of magnesian lime (35.8 per cent magnesia, 53 per cent lime), and from 10 to 11 per cent of tar. The bottom is rammed up around ordinary tuyeres. Strangely, these tuyeres are more rapidly attacked than the lime mixture around them, the greatest destruction going on during the afterblow. The bottoms stand from 15 to 20 blows,

and the vessel lining 80 to 100. As for the grade of pig worked, Creusot started with 0.9 phosphorus, and failed, increased to from 1.7 to 1.8 per cent, and did better; and has now reached from 2.50 to 3 per cent, which is believed insures good results. Silicon is kept low, about 1-3 per cent being maximum, ordinary amount. Carbon ranges 3 per cent, and manganese from 1.50 to 2 per cent. Sulphur must not be greater than 0.20 per cent. This is evidently the weak point, as it requires heavy quantities of lime, high temperatures, and considerable manganese in the charge of the blast furnace to produce pig so low in sulphur from ordinary ores. The charge of this pig at Creusot, where it is taken directly from the blast furnace, is 8 tons in a 10-ton acid converter, which has been previously charged with 18 per cent of strongly pre-heated lime, and 1.5 per cent of fluorspar. About 10.5 to 12 minutes after the beginning of the blow, at the close of the decarbonizing period, the blast is stopped, and what fluid cinder there is then poured off. This cinder is high in silica (22 per cent), in lime and magnesia (47 per cent), and in phosphoric acid (12 per cent). Then a second addition of 5 to 6 per cent of lime is made, and the afterblow begins. This lasts 4 or 5 minutes, and as much as possible of the cinder is poured off. This cinder runs 12 per cent of silica, 54 per cent of lime and magnesia, 11 per cent of oxide of iron and manganese, and 16 per cent of phosphoric acid. The charge of spiegeleisen with 18 per cent of manganese is 10 per cent of weight of pig. One-third is put into the steel when in the converter, and 2-3 when in the ladle.

The average composition of basic and acid rail steel at Creusot is as follows:

	BASIC.	ACID.
Carbon	0.430	0.400
Silicon	trace	0.300
Manganese	0.760	0.660
Phosphorus	0.060	0.075
Sulphur	0.029	0.040

The characteristic of basic steel is the absence of silicon. Phosphorus, it will be noted, is lower; while with sulphur, if great care be taken, a very good metal can be obtained. On the whole, experience at Creusot has shown that chemically, basic steel can be made of a more uniform and of a better quality than ordinary acid Bessemer steel. As for the physical structure of the steel, blow holes were troublesome at Creusot in the beginning. It was found, however, that an increase in the percentage of phosphorus in the pig proved beneficial, and direct experiment, by running a blow hot and a similar charge cold, by the addition of scrap, showed that the inference that this was due to a hotter finish produced by higher phosphorus was correct. Highly pre-heating the basic additions was adopted with the same end in view.

The quality of the steel made by the Basic Process has been thoroughly ascertained, as far as analyses will reveal it, and pretty well determined by physical tests, both hot and cold. The soft and medium grades contain very much less phosphorus and silicon than any steels can have which are made by the acid process, either open hearth or Bessemer; and they may be made practically free from both these elements. In some steel, traces only, which could not be weighed, have been found by chemists. Some dead soft Witkowitz steel has P. 0.005 to 0.008 by Seraing analysis, and some Witkowitz plate steel blown and rolled, had P. 0.017 by Creusot analysis. Phosphorus in basic steel ordinarily runs from 0.04 to 0.06; it sometimes reaches P. 0.14, but this amount can always be prevented by proper overblowing and subsequent treatment, as already explained. There is no more uncertainty about removing phosphorus in the basic process than there is about removing carbon in the acid process; enough blowing will positively always do it. Silicon is always reduced to a trace or a few thousandths. Sulphur is reduced about 60 per cent.

It is this remarkable purity and mildness which, together with its cheapness, is likely to give the basic steel an enormous use for boilers, ships, bridges, and all structures requiring toughness. It seems also to fulfill all requirements for rails, tires, axles, etc. The harder grades have not been largely produced, but it is well ascertained that they may be, without risk of brittleness from taking up phosphorus, as already explained.

Those occupied in the manufacture of Bessemer steel know how difficult it was to obtain, with regularity, the extra soft steel employed for boilers in the French navy. Such metal appeared only to be made in the Martin furnace, and even then it was necessary to employ picked material in its manufacture. But by the new Bessemer dephosphorizing process, steels of an extraordinary degree of softness is obtained with the greatest facility, and at a price less than that of ordinary rail steel. By treating a pig containing from 1.5 to 2 per cent of manganese, we obtain, after the decarbonization and dephosphorization is finished, a non-oxidized metal, which does not contain more than traces of carbon and manganese. If it be desired that the steel should be entirely free from any tendency to red shortness, we may add from 0.25 to 0.50 per cent of rich ferro manganese to remove any traces of oxygenization. The only precaution to be taken to obtain a soft steel is to choose pig (if direct working be employed) which contains sufficient manganese, with 2 per cent as a maximum, or to make a suitable mixture of pigs, if cupolas be employed. But this will be by no means the only outlet for dephosphorized metal, for up to the present time the high price of soft steel has been the great obstacle which has prevented many people from employing it in construction. But by the new process soft metal can be produced at a less price than ordinary (puddled) iron. There is, therefore, no longer any

reason, apart from routine, why steel should not be employed in all cases in place of iron, to which it is so much superior in strength.

Its freedom from red shortness, is generally conspicuous, noticeably the hot tests and the plate rolling of Witkowitz steel cast after overblowing without any spiegel or other addition ; nor is the pig used particularly high or low in any element. The rather smooth rolling of basic steel at Creusot was attributed to the practicability of high heating in the absence of silicon. This quality especially adapts the steel to drop forgings and stamped sheet work, for which it is largely used. It is generally more "rising" than acid steel, but this difficulty may be mitigated by proper casting, as before indicated.

The inquiry is largely and anxiously made : Will basic steel take the place of wrought iron for welded work, in the innumerable country blacksmith shops where, in the aggregate, such a large quantity of material is used, and where the new material will, for a long time, be accepted or condemned, as it stands or fails under old temperature and methods? It is probable that no fusion product will ever weld as easily and soundly, by old methods, as a puddled product. Through the latter there is diffused a welded powder in the shape of slag, which protects the surfaces from oxidization, and which melts and washes off oxide when it is formed. The fusion product, on the contrary, is almost perfectly free from slag and must be treated with an artificial slag, and manipulated with such a degree of skill that steel welding may be called a new art. Boiler plate clippings and ingot iron scrap are welded in the rolls and drawn into sound bars, angles, rivets, rods, etc., in various foreign works, and this material is hand welded, easily and perfectly, in the smith shops of the various steel works, and in other smith shops where the new art has been learned.

The matter of cost, which has been made so mysterious and inscrutable, is no longer difficult. We now have data as to every element, within such exact limits that any one may estimate the cost of basic steel in his own region, nearly as correctly as that of acid steel. Estimates may be safely based on the following quantities :

Waste, 15 to 16 per cent on the pig.

Lime additions, charged red hot, 18 to 20 per cent on the pig.

Lining material, 100 pounds per ton of steel.

Extra labor, say 5 cents per ton of steel.

Spiegel, 5 per cent of 12 to 15 per cent manganese.

High silicon Bessemer pig, 5 per cent.

The slag has a value, but need not be considered.

The item of greatest importance is, of course, the comparative cheapness of phosphoric pig.

The greater value of the steel for special purposes must also be considered.

These are the elements of cost, based on about an equal output of basic and acid steel ; and the basic output need be neither "considerably," nor for that matter, any less when the plant is specially designed for the basic process.

It should appear that with $5.00 per ton lower pig, the economy in waste and spiegel and the value of the slag should compensate for the lime additions and extra linings, and that the saving on ingots should be the whole difference in the cost of pig.

While there is no doubt that the economy of fuel and labor in the manufacture of steel as compared with that of iron, is more conspicuous in the case of rail making than in most other departments of manufacture, puddling has, comparatively speaking, stood still for the last ten years. Economy in steel making has made, and is making, rapid progress, and the developments and modifications introduced

during the last four years give assurance of even more rapid advance in the future.

In Germany, the manufacture of dephosphorized steel is in operation in eight large firms, viz.: Messrs. De Wendel, Herr Stumm, and the Union Works at Dortmund, each with two converters, and the works of Rothe, Erde, Bochum, Horde, the Rhenish Steel Works and Herr Gienauth. During the current year they have largely increased their make. Four works make nothing but dephosphorized metal, and each of these is said to be full of orders, for their special soft steel. Besides these, new basic works are started by the Ilsede Works, the Maximilians Muette Works, the Rohrback Works, and others. The Ilsede Works will be on a large scale, starting with four converters. The new basic plant of the Horde Works is of an entirely novel design, the ladle crane being a hydraulic crane on a locomotive carriage, and arranged so as to be able to serve three or more vessels in a straight line. Basic extensions are also in progress by the Phœnix and Oberhausen Works.

In France the Creusot works continue dephosphorizing steadily, both with the Bessemer and Siemens processes. Creusot was one of the first works to make a series of tests, and though success in the open-hearth was attained almost at the start, it took some time before anything like regular working could be reached in the Bessemer converter. Now, of course, the cause is fully understood, being chiefly the nature of the pig employed; but at the time it was used as a very strong argument against the process, and the reports of the quality of the rails made caused much alarm.

Four other large works, solely devoted to dephosphorizing are in operation, while a fifth, at St. Nazaire, though it has better facilities for obtaining Spanish ore than any other works in France, has been so arranged as to adopt the old or new process at will. The Jœuf Works has a plant, con-

sisting of four converters. The Longwy Works has three vessels, and the works of the Societe du Nord et de l'Est have two vessels. The output of dephosphorized steel in France now exceeds 3,000 tons per week.

In England, Bolckow, Vaughan & Co. are making 2,500 tons of Cleveland steel per week, and are preparing to double this output. These, with lesser works in other sections, have enlarged the actual output of dephosphorized steel in Europe, in little more than a year, from under 3,000 to nearly 9,000 tons a week. The total make is, therefore, at the rate of over 450,000 tons per year. In England, there are 6 converters building for the process, which will probably produce about 3,500 tons a week. On the Continent, there are 25 converters in course of erection for the process, with a minimum capacity of 9,000 tons a week.

The perfect success of the Basic process is therefore assured. There is now no doubt, of eliminating the phosphorus down to the merest trace, and of excluding most of the sulphur likewise. It is in successful operation already in Belgium, Germany, France and England. Little, if any, difficulty is found in dealing with French ores as they contain considerable sulphur. So well is this appreciated there, that Schneider & Co. have a "plant" in course of erection to operate this process on an extensive scale. Ores with over 2 per cent of phosphorus have been found to be as tractable as ores holding the merest trace; the most impure and inexpensive iron ores thus become as serviceable as the costlier ores. Ample evidence of this may be offered. Rails made for the British railways have passed through the severest tests and been declared equal to any made from Cumberland or Spanish hematite ore. The product has been uniformly good, likewise, on the continent, where thousands of tons of steel have been manufactured from highly phosphoric pig, and with the most satisfactory results.

The mechanical difficulties obstructing the rapid development of the new system have finally disappeared and its adoption is, in the opinion of many experts, simply a matter of availability of location, as the introduction of the basic process is certainly an innovation in steel manufacture, second to none in its history. These inventions will in reality prove no less important to the world than those of Kelly and Bessemer. Changes in the whole field of American manufacture will be involved, and also changes in the location of works, in the relative value of Lake Superior to other ores, in cost of raw material for both the open hearth and crucible processes, in the present standing of the puddling furnace, and preminently in the labor question.

The questions of commercial interest to which the introduction of the new process gives birth, therefore, inaugurate a revolution of which it is impossible to foretell the exact outcome.

CHAPTER VI.

THE HARRISON STEEL COMPANY.

A DESCRIPTION OF THE WORKS OF THE HARRISON STEEL COMPANY—THE NEW BASIC-BESSEMER PLANT, DESIGNED ACCORDING TO THE MOST IMPROVED PLANS OF STEEL WORKS CONSTRUCTION.

The site of these Steel works is located at the town of Harrison, in the County of Jackson, Illinois, on a plateau fifty feet above the waters of the Big Muddy River. The surface area covers about 100 acres.

TRANSPORTATION FACILITIES.

The railroad facilities are afforded by the St. Louis Coal Railroad to Pinckneyville, which line is in connection with the Cairo Short Line to St. Louis and to Cairo; also with the Illinois Central and its connections to Chicago and the Northwest and to New Orleans; and with the Vincennes Division of the Wabash Line, making connections at Vincennes for Louisville to Cairo, Cincinnati and the East; and again to Chester on the Mississippi River, fifty-two miles from Harrison, at which point connection is made to Iron Mountain, Pilot Knob, Shepherd Mountain, Russell Mountain, "and Southwest Ore District" by the Chester, Iron Moun-

tain and Western Railroad, now in course of construction; and at the same place, by river, to all points on the Mississippi River between St. Paul and New Orleans, and to all points on the Ohio River; and at Cairo, situated at the junction of the Ohio and Mississippi Rivers, sixty-five miles from Harrison, connection is also made with the St. Louis, Iron Mountain & Southern Railway to the Southwest, connecting there also with the Texas Pacific Railway. At Paducah, on the Ohio River reached by a projected line of the Danville, Olney and Ohio River Railway, distant about seventy-five miles from Harrison, connection is made with the Chattanooga & St. Louis Railroad to the Southeast; and with steamers and barges from the Cumberland and Tennessee Rivers.

The railroad and water facilities, so far as transportation to and from the works for finished product or materials is concerned, are deemed to be unexcelled by any other plant in this country, when considered in connection with the proximity of the raw material and the nearness of the market for the finished product.

THE WATER SUPPLY.

Water is obtained in abundance from a reservoir supplied by the Big Muddy River, 1,000 feet distant, conveyed to a well situated in the works, at which pumps are placed; thence discharged into six tanks 25 by 15 by 6 feet each, from which supply pipes lead to all the various departments of the works. The water is good, containing nothing of an injurious character to boilers or to the packing in the cranes, and is what is technically known as "soft water."

FUEL.

The works set upon and are surrounded by coal fields of large extent. The coal is a good coking or free coal, and of excellent quality for fuel and iron smelting.

Its character is shown by the following analysis, made by Messrs. Potter & Riggs, of the Washington University, St. Louis :

Moisture	6.90 per cent.
Volatile matter	31.33 per cent.
Fixed carbon	56.02 per cent.
Ash	5.75 per cent.
	100.00 per cent.
Sulphur separately determined	0.83 per cent.

This coal, seventy-five feet below the surface, is the No. 8 of this series of veins nine to ten feet thick, and is the highest vein developed in the Mississippi Valley.

Underlying this vein, at a depth of forty feet, is vein No. 7 from four to five feet thick, and by analysis made by same chemists, contains :

Moisture	3.95 per cent.
Volatile matter	36.95 per cent.
Fixed carbon	48.55 per cent.
Ash	10.55 per cent.
	100.00 per cent.
Sulphur separately determined	1.96 per cent.

The color of the ash indicates the presence of very little iron, so that the sulphur is probably in the organic form, or in part as a sulphate of lime. The No. 7 and No. 8 veins are situated in Williamson County, seventeen miles distant from the site of the steel works, and is the coal from which the coke is made.

In Jackson County, underlying the site where the steel works are located and contiguous thereto, is vein No. 2, of from four to seven feet in thickness, known as the "Big Muddy Coal," which will be used for supplying the gas producers, and for general purposes.

These extensive coal properties are owned by the Carbondale Coal and Coke Company, and a contract for a supply

of fuel for all the requirements of the Harrison Steel Company has been made with that company for a term of twenty years, based upon a nominal profit above the cost of mining, thus insuring an unfailing supply of fuel at nearly minimum cost.

The St. Louis Coal Railroad Company and the Carbondale Coal and Coke Company are owned by the same parties, under the same management and inseparably connected for the next twenty-three years by contracts, sanctioned and ratified by every stockholder of both companies, and whose signatures are thereto attached.

ORE SUPPLIES.

Iron ore is in abundant supply in Missouri, Tennessee, Alabama, and Arkansas, and is within easy reach by the many excellent railway and river connections made with the St. Louis Coal Railroad, and its leased lines, a corporation with which the Harrison Steel Company has made a transportation contract for a term of twenty years at a certain price per ton per mile for carriage of raw materials and finished products.

UNDER THE SITE.

The nature of the soil and earth under the site at every point is as follows:

First strata, 6 feet in depth, sandy loam.
Second strata, 2 feet in depth, sandy clay.
Third strata, 5 feet in depth, sandy clay, hard.
Fourth strata, 4 feet in depth, tough clay.
Fifth strata, 3 feet in depth, tough clay, dark.
Sixth strata, 7 feet in depth, blue clay, hard.
Seventh strata, 14 feet in depth, brown clay.
Eighth strata, hard pan.
Total, 41 feet to the slate overlying the coal.

FIRECLAY, LIMESTONE, ETC.

During the excavations for the foundations of the buildings, advantage has been taken of the excellent quality of

the clay for the manufacturing of building bricks at a cost not exceeding $4.00 per thousand. The fuel is cheap, and the clay can be burned to a hardness suitable for sewers and foundations about the works.

Limestone is conveniently located, and can be brought to the works at low cost. This is an element of importance, as it is extensively used in the blast furnaces and in the basic processes. There is also an abundance of superior fire clay.

Another important feature in connection with the value of the site is the proximity of many natural ravines of great depth and width, in which the slag and cinder and other refuse can be deposited at little cost, and surface land thus made suitable for building purposes, and thereby enhancing the value of the land.

DRAINAGE.

The drainage from the works is perfect, as the general level of the site is fifty feet above high water level in the river, thus ensuring the carrying off of surplus water and other matter, leaving the foundation pits, lowered tracks, etc., dry and firm.

COKE OVENS.

The coke ovens are situated 600 feet from the blast furnaces, and the coke will be carried to the furnaces by railway up an inclined plane to stock houses at the rear of the blast furnaces, and thence elevated by steam hoist to the platform of the furnaces.

General Arrangement of the Works.

THE BLAST FURNACES.

The six blast furnaces are placed in blocks of three, but stand in such position that each furnace can be shut down independently of the others, relighted, and yet in no way interfere with its neighbor furnace ; thus one blast furnace

can be used, or the full battery of six, as is most convenient. Each furnace is provided with three stoves, and is capable of producing 1,200 to 1,500 tons of pig metal per week. The ore and lime is supplied to the furnaces in the same manner as the coke. Each set of three blast furnaces has three boiler houses adjoining each other. The two engine houses are each 121 by 75 feet, and each contains ten vertical engines.

Exceptional facilities have been provided for supplying the furnaces with material promptly and with ease, and for the removal of the cinder and refuse expeditiously, by placing the blast furnaces 125 feet apart, thus allowing ample room for railway transportation. The cinder railway, and the railway for taking the metal to the converting house, are independent tracks, thus ensuring the utmost freedom of action.

CONVERTING DEPARTMENT.

The Bessemer converting department is situated 750 feet distant from the blast furnaces on an air line, but the metal is made to traverse 1,450 feet up an inclined plane by easy gradient to attain the elevation of twenty feet. There are six converters of ten tons capacity each, side by side.

The main building is 400 by 170 feet. The spiegel cupola buildings or towers abut upon each end of the converting building, and are eighty by sixty feet, containing four cupolas in each building, of the common form, for melting spiegeleisen.

The molten metal is taken from the blast furnaces up an inclined plane in ladles on a car above and in line with the vessel in which the metal is to be converted, thereby effecting a large saving over the general practice in the United States:

1st. By avoiding the necessity of maintaining casting beds at the blast furnaces by a constant supply of sand and labor for handling same and making of moulds.

2d. By avoiding the casting of pigs and the loss of heat occasioned by their cooling; the cost of labor in raising, breaking, lifting and loading of the pigs at the blast furnaces, the unloading and reloading at converter department; the raising to cupola charging door at least fifty feet above the floor line; the maintenance of cupola; the cost of fuel to effect the melting; the maintenance of blowers supplying the blast; and the cost of steam and labor in running all the machinery named in this connection.

This process is working with great success in England and on the Continent, and is in successful operation in Chicago.

In line, and at the side of four of the six converters, two cupolas are placed, making eight cupolas for utilizing low cost southern pig when the same is for sale in the market, and also for making addition to charge in the ladle when on its way from the blast furnaces to attain more uniform results. Should the charge from the blast furnace be too high in silicon, a fourth more or less of pig metal low in silicon can be tapped directly into the ladle from the cupolas, which are so situated that but little delay is caused when stoppage at the cupolas becomes necessary.

The converters are placed in such a position that the vessel can be lowered on trucks by hydraulic hoists, located under the converters, and thence removed by railway to the lining department, there to be relined.

In the meantime, a spare vessel is brought in from the lining department, is inserted in the place of the one removed, the bottom replaced and the substitute vessel is ready for use, thus preventing any delay to the process of carrying molten metal direct from the blast furnace.

A saving is also made in avoiding the waste of a large amount of refractory material usually thrown away in the present practice of repairing the vessel while suspended in working position.

The lining department is 400 by 120 feet, situated in the rear of the converting house ninety feet distant, and is connected by lines of railway running from the hoists situated under the vessels in the converting department to the two turntables in the lining department. From these turntables a series of short railroad tracks radiate in such form as to accommodate ladles or converter bottoms, as the case may be. These ladles or bottoms are placed upon a truck made for this purpose, and are run exactly under a fireproof bonnet, which is supplied with gas from the gas producers.

A feature of importance in the converting department is the excellent means adopted for the removal of the slag with ease and expedition by means of the cranes and slag cars; for as a large amount of slag is formed in the basic process, especial facilities must be furnished for its prompt removal, and with as little cost as possible.

The engine building for the converting department is 150 by 108 feet, and contains four engines and six pumps. There are three buildings, twenty-five feet apart, for boilers, each 150 by 45 feet, located near this department.

The metal is poured into moulds made suitable for the various products to which it is intended. Such as ingots for plates, shafting, merchant bar, tire, wire rods, hoops and cotton ties, castings, blooms and billets for industrial establishments, in place of iron, and which can be furnished them at less cost. The ingots are loaded on railway trucks and conveyed to the Siemens heating furnaces in the appropriate department and deposited while hot in the furnace.

For making steel castings the metal is carried in ladles on railway trucks direct from the converting department to the iron foundry, distant 250 feet, and there handled in usual way by steam cranes, and poured into the moulds.

There are three departments that receive the ingots direct from the converting department, viz.: The large merchant mill, the plate mill, and the blooming and billet mill.

LARGE MERCHANT MILL.

The large merchant mill, which can also be used as a rail mill, when necessary, is situated in a building 240 feet wide at furnace end, and 330 feet wide at hot bed end, and which in the middle is 100 feet wide the total length being 500 feet. The furnace end of the building is 90 feet from the converting house. The type of machinery in this mill has been very successfully operated abroad.

The ingots are brought hot from the converting department and charged directly into the rear of the furnace by mechanical power, and are drawn from the front on the side next to the rolls. It is expedient that the ingots be placed in the heating furnace while yet hot, and ample heating furnace capacity has been made to attain this object; the molten metal is then allowed to "set" equally, all through, to the temperature desired for rolling. When this part of the process is properly performed, the amount of second quality product will be materially reduced, and all other things being equal, it should not exceed one per cent of the finished product.

The ingot is taken from the heating furnace, bloomed, roughed and formed in a three high set of rolls, with hydraulic lifts and automatic "turning devil." Thence it is run on driven rollers to the reversing finishing rolls, situated at some distance behind the blooming rolls, and worked backward and forward through the rolls on the floor level until it is reduced to the desired shape and size, such as angle, "tee's," square, round, flat, or concave, and to not less in weight than 1,000 pounds to the piece. This mill has a capacity of 400 tons per day, more or less, according to description of the order being worked. The rolls in this mill are driven by one direct engine and one double reversing engine.

PLATE MILL DEPARTMENT.

The Plate Mill building is 150 feet distant from the converting house, and is 300 by 210 feet in dimensions.

The ingots or slabs are brought directly from the converting department hot, and are charged into the rear of the furnaces by hydraulic cranes situated between the heating furnaces with mechanical devices attached, rendering this operation comparatively cool and easy, no manual strain being required.

The ingots are taken from the heating furnaces to the rolls by an overhead track or "telegraph" on an incline six inches to every twenty feet, rendering the transfer an easy matter. The rolls for the plates are designed to reduce the stock speedily while in good heat. The middle roll is hollow and a continual stream of water passing through prevents this roll from heating to such a degree as to cause excessive expansion and contraction, the middle roll being subject to double the amount of heat of either top or bottom roll. There are two plate mills in line with each other having two-high breaking down rolls, and three-high finishing rolls.

The roughing rolls are thirty inches in diameter by 108 inches in length, and the top and bottom finishing rolls are twenty-four inches diameter by eighty-four inches in length, the middle roll being twenty-six inches in diameter. The plates are handled by hydraulic lifts throughout the whole process.

Large floor room has been provided in this department as an essential for the cooling of plates so that they may be readily cooled for shearing, and the machinery for this operation is of massive and modern design, of the Wellman type.

The bed plates under the rolls are of such length as to suit the finishing of plates as large as are used for boiler

heads, the largest at present being eighty-four inches in diameter.

Tank and boat building steel will also be made in this department.

THE BLOOMING AND BILLET MILL.

The Blooming and Billet Mill is situated 530 feet distant from the converting house, and is in a building 145 by 165 feet. The ingots are brought hot from the converting department on railway trucks, and charged in the rear of the furnaces and removed from the front next to the rolls.

A thirty-six inch reversing train is turned in grooves to form slabs from twelve inches wide to four inches thick and upwards for plates; also, blooms six inches square or more for merchant bars of all sizes. In the case of billets, for hoops, cotton ties, wire rods, and other small work, the six inch blooms are cut at a pair of steam shears, so placed as to be fed by driven rollers, and the cut blooms pass into a twenty inch three-high billet mill, placed close to the shears, and there reduced to any size greater than one and a half inches square, at the same heat from the ingot, and are handled by hydraulic lifts while being rolled.

The reversing mill is driven by a reversing double engine, and the three-high mill by a single engine.

THE WIRE ROD MILL.

The Wire Rod Mill is situated 135 feet distant from the blooming and billet department, and is in a building 565 by 220 feet.

The one and a half inches billets are brought on cars from the blooming department, and charged in rear of the Siemens furnaces, which are of ample capacity to receive and take care of the billets necessary to keep the rod mills full at all times. This department is supplied with two compound rod mills, and to each rod mill there are attached two

continuous roughing trains placed side by side, and driven by one engine with connecting clutch between, so that should any repairs or fitting be required to the continuous train while in operation, the other train can be turned on and any stoppage for that cause prevented. After the billet has made eight passes, or rather reductions, in the continuous train, it is conveyed to a three-high finishing train fitted with "repeaters," and there reduced by square and oval passes alternately to a No. 5 wire gauge rod in the usual way. The three-high train is driven by a separate engine. The reels on which the rods are coiled are located near the sunken track, and the rods, when taken off the reels, are thrown on the open cars, weighed on track scales, and are ready for shipment.

THE HOOP, COTTON TIES AND SMALL MERCHANT BAR MILL.

The Hoop, Cotton Ties and Small Merchant Bar Mills are situated 200 feet distant from the blooming and billet department, and in a building 650 by 110 feet. The billets are brought on railway trucks direct from blooming and billet department, and charged in rear of four Siemens furnaces, and removed in front and taken to the rolls. A sunken track runs through the department, so that the product can be readily loaded on cars with the minimum of handling.

It may be remarked in this connection that all the tracks on which the railway trucks carry material for charging into furnaces, are laid on the general level.

In the Hoop Mill six passes are made in a continuous train, and the finishing passes are made in the usual way. The two Merchant Mills in this department are sixteen inches and fourteen inches diameter rolls, respectively, for merchant bars, with a specialty for shaftings less than three inches in diameter.

THE UNIVERSAL MILL.

The Universal Mill is situated 780 feet distant from blooming department and is in a building 280 by 150 feet. The steel is brought from the blooming department on railway trucks and charged into three Siemen's heating furnaces.

There are here twin reversing engines with rolls and automatic tables fitted with feed rollers, and one hot straightening table, for the manufacture of Universal bar.

THE SHAPING SHOP.

The Shaping Shop is situated thirty feet distant from the Universal Mill, and the size of the building is 280 by 110 feet and is for construction purposes and where large merchant bars can be sheared to any curve or angle and punched to suit drawings and specifications that may be furnished.

THE FORGE DEPARTMENT.

The Forge Department is situated thirty feet distant from the shaping shop, and the size of the building is 280 by 90 feet.

Steel is fast taking the place of iron for forging. Its greater homogeneity, strength and consequent endurance is driving iron out of the market as surely as the steel rail has superseded the iron rail and steel wire has taken the place of iron wire. Piston rods, connecting rods, bars, links, shafts, cranks, axles, and general forgings will be ordered made from steel of a certain chemical analysis; as in fact all industrial works in ordering steel for their products will specify the kind of steel they desire, which must contain fixed chemical proportions determined by analysis. In this way a product better suited for the resistance of specified strains can be furnished by the steel maker with better guarantee than can be done by the iron maker.

THE FOUNDRY, BLACKSMITH SHOP AND MACHINE SHOP.

The Foundry, Blacksmith Shop and Machine Shop are in three separate buildings, thirty feet apart, lying parallel to each other, the blacksmith shop being located between the two, and they are bounded by the converting department on the one side, by the large merchant mill on another side, by the plate mill on another side and by the shaping shop and forge on the remaing side.

The Foundry is 215 by 120 feet.

A track runs through the centre into the machine shop and the roll turning shop. There are two large cupolas situated at one side in the middle and one small cupola at one end. To the charging platform in the yard there are two inclined planes for the convenience of the workmen. There are four steam cranes, annealing furnace, two large core ovens, core benches, etc., and appliances for moulding by loam, dry sand, green sand and chill moulds. In one corner of the foundry is a crucible furnace and a small cupola for melting the material for brass castings, which comprises the brass foundry department. In another corner is a furnace for melting babbitt metal and here the engine and mill brasses of the works will be "babbitted." Besides making all the iron castings, ingot moulds, etc. required by the works, it is designed that this department shall also include steel castings in its product, not only for the needs of the works but for the market, such as wheels and pinions, dies and hammer heads. The manner in which the metal is carried into the foundry from the Bessemer department has been referred to, the open-hearth steel is brought in a similar manner from the Siemens-Martin department.

The manufacture of steel castings in Europe has been within recent years enormously developed through the cheaper systems of manufacture by the Bessemer and Siemens-Martin

processes, and the conclusion is justified that they will very largely take the place of castings of pig iron. Bessemer steel castings are not yet quite so common as those of the open hearth metal. The greatest difficulty experienced in adopting Bessemer steel castings is, of course, the blow holes caused by the escape of gases which have not reached the upper surface of the casting previous to its cooling. To remedy this difficulty various processes have been proposed and adopted. At Terre-noire, patient research has perfected the manufacture of steel without blow holes by using a silicide of manganese and iron, which gives to the product remarkable qualities. The silicon prevents blow holes by decomposing the oxide of carbon in dissolution, which tends to escape during solidification. The manganese reduces the oxide of iron, and prevents a further reduction of gases by the reaction of the oxide on the carbon. In the decomposition of oxide of carbon by silicon, silica was produced, and afterwards a silicate of iron, which remained interposed within the steel. The manganese allowed the formation of a silicate of iron and manganese, which is much more fusible, and passes into the slag.

The principal obstacle to the production of soft cast steel consisted in its excess of carbon. This was overcome at Terre-noire by the industrial production of alloys of iron, silicon and manganese, containing a specially high percentage of this latter substance. This alone allowed of a sufficient quality of silicon being added near the close of the operation, without at the same time introducing too much carbon. Such an alloy has been produced, containing 8.10 per cent silicon, 14.50 of manganese, and 1.30 of carbon. Soft homogeneous steel, without blows of any degree of hardness can now be made at the mill of the manufacturers, varying in hardness from that suitable for projectiles to the softest qualities needed for any constructive purpose. This

steel is satisfactory as to its powers of resisting strains, its limits of rupture, and elongating properties, as well as in resistance to shocks.

The greater regularity and uniformity obtained in crucible steel castings, up to recently, apparently enabled them not only to hold their own as against the cheaper modes of manufacture, but even to find new applications almost daily. Steel-castings, however, have manifestly such a vast field yet to occupy, that the product of the crucible can only come into successful competition with those of the converter and the open hearth, where an exceptionally high quality of metal is demanded.

The Blacksmith Shop is 215 by 90 feet, and contains two heating furnaces, one large steam hammer and two smaller ones, and a number of blacksmith forges; also, shears, benders, punchers, and other necessary tools.

The Machine Shop is 215 x 90 feet and is two stories high, the second story being for the use of the pattern shop and draughting room. It is furnished with a number of lathes of various sizes, planes, drilling machines, slotters, shaping machines, bolt cutters, pipe cutters, vise benches and other tools.

A track runs through the centre of the shop and the tools and tracks are swept by four cranes.

ROLL TURNING DEPARTMENT.

The Roll Turning Department is situated sixty feet distant from the shops just described and abuts on the building of the large merchant mill. Its size is 135 x 70 feet, and it is furnished with cranes, roll turning lathes for large and small work, and other appliances for the care and maintenance of the rolls of all the departments. The shops and roll turning department are connected by railway tracks on the general level, for convenience in handling and removing materials in these departments.

THE BOILER SHOP.

This is a building 150 x 90 feet and is 400 feet distant from the converting department, and it is about 250 feet from the plate mills. It is fitted with all the tools necessary for the manufacture of boilers, ladles, converters, etc., and is connected by a track with the general railway running through all the departments.

SIEMENS-MARTIN PLANT.

There is also a Siemens-Martin Plant located in a building, 105 by 105 feet, and 100 feet distant from the blooming and billet department, and 330 feet distant from the plate mill department. Here is utilized all the scrap metal made about the works and the rejected product of the various departments, by melting the scrap and other metals in the open hearth furnaces in the manufacture of ingots for spring steel wire rods, spring steel, agricultural implement steel, steel castings, and for the other purposes for which open hearth steel is preferred.

It contains two ten ton furnaces and modern appliances for handling the ladles and ingots. The metal for open hearth steel castings is carried in ladles on railway trucks to the foundry as before described.

LABORATORY.

There is a laboratory connected with the works, where chemical analyses and tests of the raw material used in manufacturing the steel, and of the finished products before leaving the works, are made and recorded.

In the mechanical testing house, where the bending and tensile tests are applied, duplicates with stamped numbers are made and records kept of each. The testing, shaping and bending machines are specially designed for that purpose.

GAS PRODUCERS.

The 160 gas producers, located in the extreme southwest corner of the works, are constructed upon the most approved principles, and are in sufficient number to supply the entire works with the gas required. The roof is in two sections, and is 650 by 100 feet, supported by iron columns. The coal is supplied to the producers from cars on an elevated railway, with spouts of sufficient length to contain one car of coal, so that the dumping cars can be at once unloaded and returned to the mine, and the spout being in direct connection with the hopper of the producer, it is thus kept continually supplied with coal, which avoids the necessity of shoveling, and at the same time prevents in a great measure the formation of carbonic acid. This acid is a source of much loss, and is an annoyance to the melters, heaters, and gas men.

BOILERS.

The boilers supplying the power to the machinery of the whole works are so placed as to obtain heat from the blast furnaces and the gas producers, this method being the cleanest as well as the most economical way of making steam.

Besides the boilers before referred to, located near the blast furnaces and near converting department, there is a boiler house located near the large merchant mill, which is 150 x 54 feet.

THE STORE HOUSE.

The Store House is situated in about the centre of the works in a building 130 x 65 feet, which abuts upon the plate mill building. It is divided into compartments suitable for holding the various stores received and distributing the supplies to the various departments of the works.

THE RAILWAY SYSTEM.

The railway system is very perfect, supplying all the wants of an extensive rolling mill plant in the way of car-

riage without turn tables. It consists of a track about five miles in continuous length and is operated by small locomotives. All the departments of the whole plant are conveniently connected by railway tracks of the ordinary gauge. Raw material is brought in on elevated track 30 feet above the floor level. All the moving of the material in process of manufacture is handled by pony engines on the ground floor tracks, and all finished product is shipped from each department by sunken tracks four feet below the floor level. In some of the buildings the platform of the cars constitutes a portion of the building, thus forming a movable floor and making the transfer of heavy material easy from one part of the premises to another.

In other buildings the top or platform of the cars is a little below the general level and the product is easily pushed or rolled on slides to the cars.

CHARACTER OF BUILDINGS AND SEWERAGE.

All of the buildings are of brick with cast iron pillars and iron roofs.

Sewer flues and gas flues extend through the works and in such positions that they can be reached for cleaning and repairs with ease.

THE WIRE MILL DEPARTMENT.

The Wire Mill Department of the Company is situated in the city of St. Louis, near the Union Depot Junction of all railways into the city. The works cover about four acres, and contain a rolling mill, four wire-drawing departments, one galvanizing department, four annealing departments, five wire-cleaning and drying departments, bale tie department, and wire rope department.

The rolling mill contains two single puddling furnaces, six blooming fires, one two and one-half ton steam hammer,

seven heating furnaces, one two-high eighteen inch train of rolls, one rod train and four engines.

The daily capacity of the rod mill is forty tons.

The wire departments contain 450 wire-drawing blocks and three engines; daily capacity 100 tons of all kinds of wire.

The galvanizing department contains eight galvanizing pans, with appropriate furnaces and machinery; daily capacity forty tons.

The annealing departments contain eight muffler furnaces and twenty-eight pot furnaces.

The cleaning and drying departments are provided with numerous appliances for the proper cleansing and drying of the wire after it has been annealed.

The bale tie department has a number of straightening machines, in which the wire is straightened and cut into suitable lengths for baling hay.

The rope department contains six machines for making the strands and forming the rope.

Rope of all sizes, from one-fourth of an inch diameter to three inches in diameter, and for the various purposes for which wire rope is required, is made in this department on machines of new and improved construction, so as to secure perfect uniformity of lay under severe tension, and without tension to the wires. The sales of the wire department of the Company now approximate $2,000,000 per annum.

The quantity of steel now employed in the manufacture of wire has assumed large proportions within the past few years. So sudden, indeed, has been the increase that the steel works of the United States are not prepared at this date to furnish the wire rods required by the wire mills. The importations for 1881 were upwards of 100,000 tons, and in 1882 will exceed 150,000 tons. The most of this is used in the manufacture of fencing wire, and the adoption

of barbed wire for fencing by the farmers and the railroad companies is the cause of the enormous increase in the production of steel wire. It is only a few years since that wire rods were made from the product of the puddling furnaces, blooming fires and from piled wrought scrap iron, but by the introduction into this country of the soft Bessemer steel wire rods from Europe, those processes have been nearly abandoned, and the attention of American steel makers is now prominently attracted to this new and growing industry. The importations are principally from Germany, and the soft steel now made especially for these rods by the basic process, is in high repute with United States wire drawers, for its toughness and ductility. It is very much softer than rail steel, containing but 0.10 to 0.15 per cent carbon, while rail steel holds 0.30 to 0.40 per cent of carbon, and the latter on this account is in disfavor with wire drawers for fencing wire purposes, by reason of its hardness and want of uniformity, which greatly enhances the cost of wire making through the frequent annealing and drawings it has to be subjected to in the process of reduction from the rod. Up to the last decade the use of steel wire was confined to the manufacture of needles, fish hooks, music strings, umbrella frames, and small tools. As the demand for such wire was increased by the growth of the railway and telegraph systems, and by the development of our mines and collieries, greater attention has been paid in Europe to its economical manufacture, and to the production of a quality at once remarkable for its strength and for its uniformity. Annealing, or cooling down slowly from a red heat, has the same effect on wire as on wrought iron, that is to say, the ductility and softness of both are increased, but their elasticity and breaking strength are diminished. Steel wire has, at least on an average, twice the ultimate strength of iron

wire, and a proportionately greater elasticity, comparing diameter with diameter.

These qualities allow steel wire rope to be made of little more than half the weight of iron wire rope, with the same ultimate breaking strength. The additional elasticity of steel wire rope renders it much more supple, and less liable to injury through being bent over a drum. A steel rope easily straightens of itself after being bent even to a small angle, which is not the case with iron wire rope. The duration of all ropes is very greatly influenced by the many bendings to and fro to which they are subjected, and these influences are intensified by corrosion. Both the mechanical and the chemical sources of deterioration act in a less degree on a steel wire, as it is stronger and is at the same time less subject to corrosion, as the carbon it contains, however slight, impedes the action of rust. Steel wire ropes have come rapidly into use for mining purposes, especially in deep pits, where the light weight of rope is of such importance both for safety and the economy of working. For railway inclines, lifts, and elevators, and ships rigging the same reasons have brought it into use, and it is also extensively used for hawsers, bridge cables, clothes lines, and sash cords.

Furniture springs made from high grade steel wire cause demand for a considerable amount of steel, and is required for making springs for mattresses and furniture. The wire is given the color of copper by immersion in a solution of blue vitriol, and it is then burnished by drawing it through a hole in a die plate. Other large and growing demands for steel wire in very considerable quantities are: wire bale ties for baling hay, binder wire for self-binding harvesting machines, check rower wire, bright annealed and coppered wire for tinners, wire for wire cloth, and wire for the manufacture of wire goods generally.

CAPACITY OF THE WORKS.

Name of Department.	Tons per day of two turns.
Blast Furnaces	1,200
Converting Department	1,000
Siemens-Martin Department	50
Blooming and Billet Mill	300
Large Merchant Mill	400
Rod Mill	200
Plate Mill	100
Small Bar Mill	72
Universal Mill	60
Hoop Mill	60
Shaping Shop	
Forge	
Wire Mill Department	100

SUMMARY.

A careful consideration of the foregoing description of this new American Basic-Bessemer plant will show it to be possessed of many unusual advantages.

The site of the works combines in a remarkable degree the essential conditions of success in steel making. For the cheap transportation of raw materials to the works and of the finished products to market the water and railway facilities leave little to be desired. Inexhaustible fuel of first-class quality for gas making and for coking is found upon the spot. Limestone of the best description can be procured within a radius of fifty miles of the site, and fireclay is abundant within one hundred miles from Harrison. Good and sufficient water is found at the door of the works, and the ore supply is obtained from mines within a radius of two hundred miles, some of the principal deposits being as near as one hundred miles. Located in natures greatest food-producing section—the Mississippi Valley—food is, and always will be, cheap, and added to the eligibility of the site is the advantage of a vast home market for the product of the works within a radius of 300 miles.

At present no steel castings are made west of Pittsburgh for the supply of the Mississippi Valley, and the United States manufactures no soft Bessemer steel suitable for industrial establishments, excepting the Albany and Rensselaer Iron and Steel Co. at Troy, N. Y. This class of steel which by the present system of manufacture and supply is extremely costly in comparison with the cost of foreign material, will be a specialty with the Harrison Steel Company, and it is the intention of the company to branch out into the hitherto unessayed fields of manufacture in this country, and a ready market for all its production will be at once established, while the superior location of the plant will likewise enable it to compete successfully in all the other various departments of steel manufacture. The Bessemer steel works of the United States have confined the product of their converters almost exclusively to the production of steel rails and rail carbon steel, which have been made from pig metal too high in cost and with material exceedingly more costly than by European practice, and the open-hearth steel works of this country also obtain their raw materials at so high a cost that the product of their furnaces is limited to certain specialties of high market value. It is a fact that the raw materials alone used by the Bessemer and open-hearth furnaces of this country cost as much as the finished product of similar furnaces in Europe.

The cost of a ton of Bessemer steel rails in the United States varies according to the location of the mills in regard to raw materials and the adequacy of the blast furnaces in connection with the works. Those most favorably situated and producing their own pig, make rails at about $40.00 per ton. Others not so well situated, and which buy their pig, range to $5.00 more per ton. There are other mills making their own pig, but which owing to their remoteness from some of the raw materials, can not manufacture steel rails at any less cost than those who buy pig.

At Bolckow, Vaughan & Co., in Europe, the cost of steel rails per ton is not quite $20.00, and the works would gladly make contracts for their total production of steel rails for the next ten years at $25.00 per ton on board of ship, and take all the chances of the future market. But as they are so well located, and own nearly all the raw materials they would require in that time, with a splendidly equipped works combining all the essential conditions for economical production, they would take little risk in the cost of manufacture.

This comparison amply demonstrates how much remains to be accomplished in the United States, how great the changes in methods of working must be, and how much the exterior costs, principally that of transportation, must be reduced before such a standard of results can be achieved. The North Chicago Rolling Mill Company has materially reduced the cost of production by the adoption of improved methods of manufacture, but transportation still remains a heavy item of expense. Chicago is more advantageously situated for the procurement of Lake Superior ores than Cleveland, Pittsburg, and other eastern points, but the latter have better fuel facilities. All, therefore, labor under burdensome transportation costs, either on ores or other raw material, so that while the adoption of improved methods of manufacture, or of the direct process of manufacture might secure to them some benefits in the way of lessening the cost of production, the disadvantages of location would still be retained. Favorable as is the situation of the Pittsburg Steel Works in certain respects, the carriage charges on raw material for the manufacture of one ton of pig iron approximate $10.00 per ton. Considering the high price of skilled labor in America, this renders high tariff protection necessary to their very existence, as Europe in shipping to the United States can make available the whole length of

the coast line, with the manifold canals, large lakes, and rivers to reach by water the point nearest for shipment to the individual purchaser by railway, if necessary, thus decreasing to the minimum, the heavy cost of railway transportation.

To compete, therefore, with the advanced mills of Europe and their many natural advantages, the requirements are few in number, but they are vitally essential. They may be rapidly summed up as follows:

The works should be located specially with reference to the proximity of the raw materials to be used and the cheapness with which the finished products can be carried to their destination. This secured, methods and processes must be adopted by which the raw material may be transformed into the product without the expensive process of first converting into another raw material. The works must be situated where the accessibility of the fuel, the ore, the limestone, the water and the fire clay supply is best combined with contiguity to the market to escape the excessive costs of the handling and freight charges and of other items of avoidable cost, which now raise the price of the raw material in America to that of the finished product in Europe.

The Harrison Steel Company, it is thought, combines in its methods, processes and site, all the conditions requisite to success.

CONCLUSION.

THE STEEL EMPIRE.

The aim of this book has been to place before the public, in as concise and satisfactory a manner as practicable, some of the more important facts and statistics relative to the steel workshops of the world; that a better understanding might be gained of the various methods in vogue, and a better knowledge obtained of the truth, as to certain matters, which for reasons now immaterial to explain, have never before been given to the public; and if this hastily prepared work aid, ever so little, in the advancement of steel interests, its purpose will have been attained. In no instance have facts been stated as facts which can not be sustained by recognized authorities.

The future of the empire of steel remains substantially unrestricted, the possibilities of still further conquests from the realms of the other metals limitless. The monopolistic traditions of the iron makers disappear, one by one, in the blue-flamed crucible of the steel scientist. It is accomplished that high grade steel may be produced with about one-fourth the fuel and one-third the labor required in the manufacture of rolled iron, and the effect of this remarkable progress of the Bessemer processes upon the metallic industries of the world, has been startling in its consequences and overwhelming in the consequential depreciation of many

millions of invested capital. For almost every purpose for which iron has been used in times gone by, steel, manufactured by these processes, is now preferred. It is applied to the making of armor plates, projectiles, ordnance, tires, axles, wire, stamped ware, forgings, castings, brake blocks, masts, spars and yards, sleepers, pens, cutlery, and bells; and for the construction of bridges, for railway purposes, for the building of ships, and for boiler construction holds unrivalled supremacy.

The subject of the manufacture and manifold applications of steel seems practically inexhaustible, and the dominancy of steel where once it has attained a footing, is indisputable. Rich as the past has been in victory, genius and enterprise point to achievements of still greater magnitude.

The versatility of its uses constitutes the chief value of this peculiar metal. The massive engine, towering in powerful grandeur, the greatest of man's conceptions; the superb ærial pathways, with their thousands of component parts, crossing broad rivers and above the high masts of ships, the needle of the housewife and soil blade of the husbandman; the larger creations of commerce as well as the smallest, are produced in this magic crucible; and there are not lacking those that predict the invasion of the dominion of copper, and even the displacement of silver in the manufacture of articles of ornamentation. And difficult as it may appear to be to demonstrate the limits of the territory of steel usefulness, just as impossible, seemingly, is it, to set the limitation of its production. Recent discoveries have indefinitely increased the available resources. The eye of science, searching the recesses of the possible, has laid bare processes by which ores, hitherto unsuited to the manufacturer, may be cleansed of their deleterious substances, and thus by one of the chemical triumphs of the age, the cheapest of iron ores will rank with those richer and comparatively

limited ores, that, until this discovery was made, were deemed unfit for the steel furnace. Of raw material, therefore, the supply will be more than plentiful. But the fear of the effects of over-production need not be excited; for, as the uses of the product multiply, and the cost of manufacturing lessens, so will the applications of the product to the necessities of life become enlarged. Of many changes in the progressive movement of steel it is impossible at this time to take cognizance. The irksome work of the puddler is being superseded by less arduous, and in the main by less skilled labor. An estimate by one of the greatest authorities is, that to convert fluid cast iron into steel requires but one-third the labor that is necessary to convert pig metal into wrought iron, and that the fuel consumed in the former, is but one-fourth of that consumed in the latter operation. Economy of fuel at once therefore appears as a most important corollary of the advance of steel; yet even this great economic feature of production dwarfs in comparison with the impetus gained through the reputation this incomparable metal is securing for lasting strength and endurance.